Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

CONVENTION NUMBER

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Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
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Association of

IRON AND STEEL ELECTRICAL ENGINEERS

EXTEND A CORDIAL INVITATION
TO ATTEND THEIR

Twenty-fifth Convention

AND

Iron and Steel Exposition

JUNE 17-18-19-20-21, 1929

WILLIAM PENN HOTEL

PITTSBURGH, PA.

Technical Sessions 9:00 A. M. to 1:00 P. M.

IN OUR THREE DIVISIONS

Electrical Engineering Division

Combustion Engineering Division

Safety Engineering Division

EXPOSITION HOURS

Monday	opens at 1:30 P. M., Closes at 9:30 P. M.
Tuesday	opens at 1:30 P. M., Closes at 9:30 P. M.
Wednesday	opens at 1:30 P. M., Closes at 9:30 P. M.
Thursday	opens at 9:30 A. M., Closes at 12:30 P. M.
Friday	opens at 1:30 P. M., Closes at 9:30 P. M.

Friday Evening—Maintenance Department Employees

Teel 67

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1928-1929

C. S. PROUDFOOT, President, Vanadium Corp. of America, Niagara Falls, N. Y.

F. W. CRAMER, *1st Vice Pres.*—Republic Iron and Steel Co., Youngstown, Ohio.

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General Convention Committee

R. M. HUSSEY, *General Convention Chairman*

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General Registration Committee

R. R. SHEPHERD, *Chairman*

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Official Opening of Iron & Steel Exposition

C. S. PROUDFOOT, *Chairman*

R. B. Gerhardt, W. S. Hall, J. H. McElhinney, W. T. Snyder, L. C. Edgar

Monday Evening Informal Reception

A. A. STEWART, *Chairman*

J. R. Lewis, F. Waldorf, B. J. Ballard, Geo. Stimple, J. J. Bangert, F. J. Brittingham, Paul Caldwell, N. C. Goin

Thursday Evening Formal Reception and Dinner Dance

W. E. MILLER, *Chairman*

L. O. Morrow, T. S. Towle, A. W. Steed, A. J. Whitcomb, H. E. Davis, Norman Allderdice, A. C. Dyer, R. F. Chaffin, E. R. Lewis, R. W. Leech, W. B. Connally, F. W. Cramer, E. S. Stickle, F. D. Egan, A. J. Standing, J. E. Wood, Saul Lavine, H. C. Mosley, G. R. Thatcher, H. E. Ransford

LIST OF EXHIBITORS AT IRON AND STEEL EXPOSITION

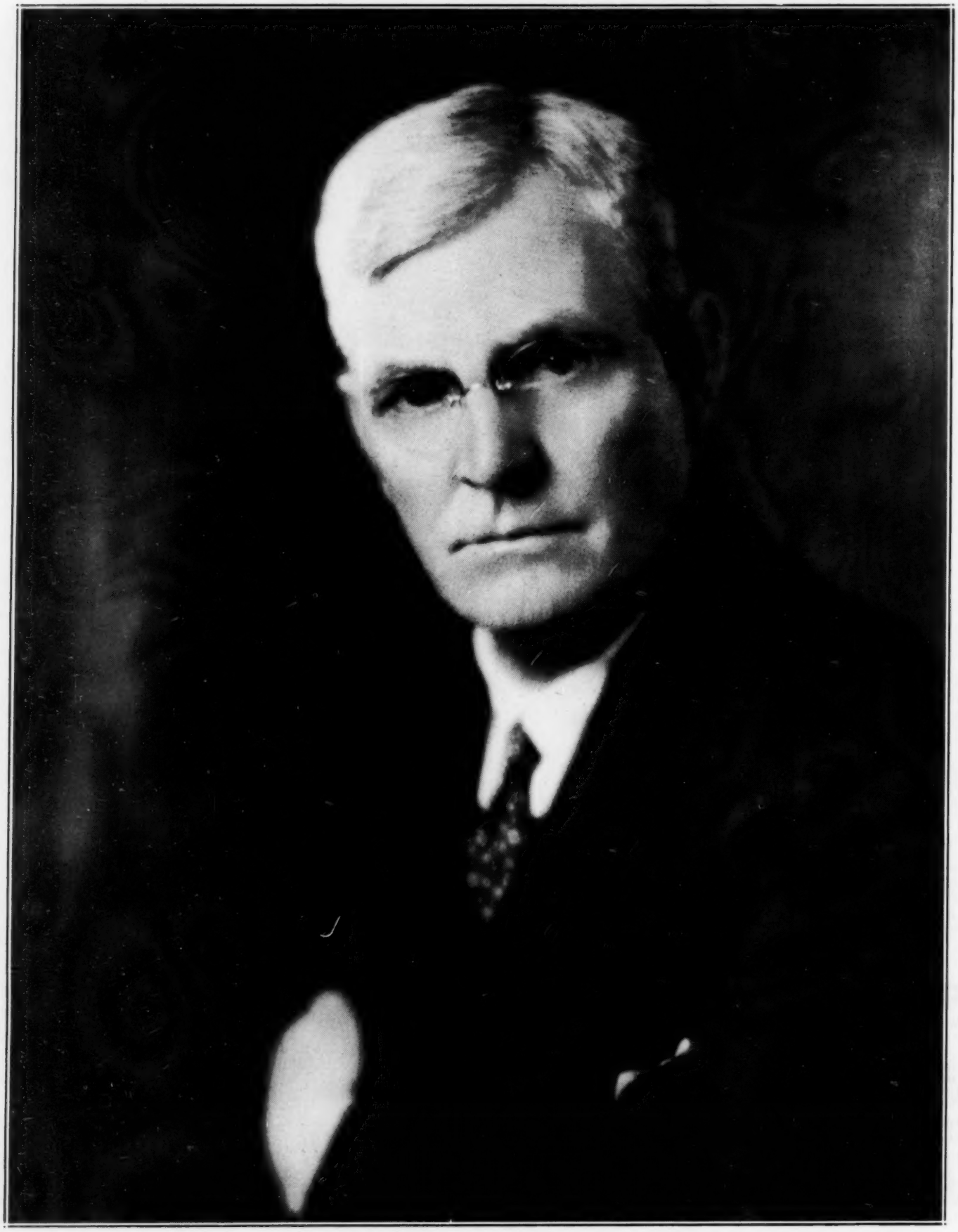
WILLIAM PENN HOTEL PITTSBURGH, PA.

June 17, 18, 19, 20, 21, 1929

Name	Booth	Floor	Room
Air Reduction Sales Co.	143-144	First	Exhibition Hall
Ajax Electrothermic Corp.	113	17th	Corridor
Aluminum Co. of America	79-80	17th	Cardinal Room
The Alliance Machine Co.	200	First	Exhibition Hall
Allis Chalmers Mfg. Co.	156-157	First	Exhibition Hall
Appleton Electric Co.	17	17th	Major Ball Room
Arch Machinery Co.	193	First	Exhibition Hall
Atlas Car & Mfg. Co.	207-208	First	Exhibition Hall
Automatic Reclosing-Circuit Breaker Co.	4	17th	Silver Salon
Automatic Transportation Co.	147	First	Exhibition Hall
Babcock & Wilcox Co.	145	First	Exhibition Hall
Baker-Raulang Co.	155-170	First	Exhibition Hall
Bartlett-Hayward Co.	36-37	17th	Reception Room
Earl B. Beach Co.	75	17th	Cardinal Room
Benjamin Electric Co.	74	17th	Cardinal Room
Wm. A. Bittner Co.	149	First	Exhibition Hall
Blaw Knox Co.	189	First	Exhibition Hall
Bristol Co.	184	First	Exhibition Hall
Brown Instrument Co.	116	17th	Main Corridor
Bull Dog Electric Products Co.	117	17th	Main Corridor
Bussmann Mfg. Co.	11	17th	Major Ball Room
Century Electric Co.	181	First	Exhibition Hall
Clark Controller Co.	53-54	17th	Reception Room
Clark Tructractor Co.	209-C	First	First Corridor
Cleveland Crane & Eng. Co.	201	First	Corridor Space
Colts Patent Fire Arms Mfg. Co.	20	17th	Silver Salon
Combustion Engineering Corp.	152	First	Exhibition Hall
Crocker-Wheeler Elec. Mfg. Co.	73-73½	17th	Interior Corridor
Crouse-Hinds Co.	23-39	17th	Reception Room
Cutler-Hammer, Inc.	42-43	17th	Major Ball Room
De Laval Separator Co.	94	17th	Blue Room
Delta Star Electric Co.	204	First	Exhibition Hall
M. H. Detrick Co.	194	First	Exhibition Hall
De Walt Products Corporation	202	First	Exhibition Hall
Joseph Dixon Crucible Co.	82	17th	Cardinal Room
Dot Lubricating Co. of Pgh.	27	17th	Major Ball Room
Doubleday-Hill Electric Co.	9	17th	Major Ball Room
Duquesne Light Co.	125	17th	Main Corridor
Economy Fuse & Mfg. Co.	58	17th	Major Ball Room
Edison Storage Battery Co.	24	17th	Silver Salon
Electric Controller & Mfg. Co.	28-29-44-45	17th	Major Ball Room
Electric Journal	122	17th	Main Corridor
Electric Machinery Mfg. Co.	180	First	Exhibition Hall
Electric Service Supplies Co.	166	First	Exhibition Hall
Elliott Company	89	17th	Blue Room
Erie Malleable Iron Works	64	17th	Major Ball Room
Fafnir Bearing Co.	205	First	Exhibition Hall
Fairbanks-Morse Co.	185-186	First	Exhibition Hall
Fort Pitt Steel Casting Co.	114	17th	Main Corridor
Frigidaire Corporation	217-A, 218-A	17th	Blue Room
Foxboro Company	5	17th	Interior Corridor
General Electric Co.	30-31-32-46-47-48	17th	Major Ball Room
General Electric Supply Co.	34	17th	Major Ball Room
Great Western Fuse Co.	111	17th	Main Corridor
Henrite Products Co., Inc.	112	17th	Main Corridor
Jno. D. Hiles Co.	150-151	First	Exhibition Hall
The Hodson Corp.	18	17th	Major Ball Room
Homestead Valve Mfg. Co.	140	First	Exhibition Hall
Hyatt Roller Bearing Co.	62-63	17th	Major Ball Room
Ideal Commutator Dresser Co.	52	17th	Silver Salon
I-T-E Circuit Breaker Co.	121	17th	Main Corridor
Ivanhoe Division Miller Co.	77	17th	Cardinal Room
Industrial Engineering	7	17th	Silver Salon
Jefferson Electric Co.	51	17th	Silver Salon
Johns-Manville, Inc.	67	17th	Reception Room
E. J. Lavino Co.	167	First	Exhibition Hall

LIST OF EXHIBITORS AT IRON AND STEEL EXPOSITION

Name	Booth	Floor	Room
W. G. Kerr & Co.	206	First	Exhibition Hall
Keystone Lubricating Co.	55-56	17th	Reception Room
Kier Fire Brick Co.	78	17th	Cardinal Room
J. Frank Lanning Co.	18	17th	Major Ball Room
Lebanon Steel Foundry	197	First	Exhibition Hall
Le Carbone Brush Co.	120	17th	Main Corridor
Lincoln Electric Co.	191-192	First	Exhibition Hall
Manning Maxwell & Moore (Shaw Crane Div.)	50	17th	Major Ball Room
Martindale Electric Co.	60	17th	Major Ball Room
Mesta Machine Co.	187	First	Exhibition Hall
Metal & Thermit Corp.	199	First	Exhibition Hall
Metropolitan Device Corp.	70	17th	Parlor B-C
Michigan Steel Casting Co.	198	First	Exhibition Hall
Monitor Controller Co.	154-158	First	Exhibition Hall
Morgan Engineering Co.	190	First	Exhibition Hall
Morse Chain Co.	6	17th	Silver Salon
Henry N. Muller Co.	25-41	17th	Major Ball Room
National Air Filter Co.	92	17th	Blue Room
National Carbon Co.	38	17th	Silver Salon
National Electric Products Co.	13-14	17th	Major Ball Room
New Departure Mfg. Co.	148	First	Exhibition Hall
Nichols Lintern Co.	66	17th	Major Ball Room
Norma Hoffmann Bearings Corp.	15	17th	Major Ball Room
Nukem Products Corp.	93	17th	Blue Room
Ohio Electric & Controller Co.	188	First	Exhibition Hall
Ohio Steel Foundry Co.	81	17th	Cardinal Room
Okonite Company	26	17th	Major Ball Room
Orange Roller Bearing Co.	84	17th	Cardinal Room
Otis Elevator Co.	203	First	Exhibition Hall
Penna. Lubricating Co.	130	17th	Interior Corridor
Permutit Company	12	17th	Major Ball Room
Pittsburgh Electric Furnace Corp.	119	17th	Main Corridor
Pittsburgh Elec. & Machine Works	8	17th	Major Ball Room
Pyle-National Co.	57	17th	Silver Salon
Pyrometer Instrument Co.	153	First	Exhibition Hall
Penna. Natural Gas Men's Association	115	17th	Main Corridor
Reed Air Filter Co.	159	First	Exhibition Hall
Reading Chain & Block Corp.	171	First	Exhibition Hall
Wallace M. Reid & Co.	83	17th	Cardinal Room
Reliance Electric & Eng. Co.	163-164-178-179	First	Exhibition Hall
Republic Flow Meters Co.	95	17th	Cardinal Room
H. Lee Reynolds Co.	141-142	First	Exhibition Hall
Roller Smith Co.	61	17th	Major Ball Room
Rollway Bearings Co., Inc.	3	17th	Interior Corridor
Rotor Air Tool Co.	87	17th	Blue Room
Rowan Controller Co.	65	17th	Major Ball Room
Rutherford & Uptegraff	1-2	17th	Parlor B-C
S.K.F. Industries, Inc.	172-173	First	Exhibition Hall
The T. L. Smith Co.	97	17th	Blue Room
Square D. Co.	40	17th	Silver Salon
Standard Underground Cable Co.	33-49	17th	Major Ball Room
H. S. Stockdale Co.	16	17th	Major Ball Room
Syntron Company	165	First	Exhibition Hall
Shenango-Penn Mold Co.	195-196	First	Exhibition Hall
Texas Company	85	17th	Cardinal Room
Thompson Electric Co.	76	17th	Cardinal Room
Timken Roller Bearing Co.	21-22	17th	Parlor-D
Tippins & Sprengle, Inc.	146-C	First	1st Floor Corridor
Tool Steel Gear & Pinion Co.	71-72	17th	Cardinal Room
Harold E. Trent Co.	123	17th	Main Corridor
Trumbull Electric Mfg. Co.	168-169	First	Exhibition Hall
Union Electric Mfg. Co.	35	17th	Silver Salon
United States Graphite Co.	10	17th	Major Ball Room
V. V. Fittings Co.	59	17th	Major Ball Room
The Weaver Bros. Co.	68	17th	Major Ball Room
West Penn Electric Co.	19	17th	Silver Salon
Westinghouse Elec. & Mfg. Co.	160-161-162-175-176-177	First	Exhibition Hall
Geo. D. Whitcomb Co.	174	First	Exhibition Hall
Edwin L. Wiegand & Co.	124	17th	Main Corridor
L. J. Wing Mfg. Co.	109	17th	Main Corridor
Daniel Woodhead Co.	98	17th	Blue Room
Yale & Towne Mfg. Co.	182-183	First	Exhibition Hall



Mr. C. S. Proudfoot, General Manager, Vanadium Corporation of America at Niagara Falls, New York. Mr. Proudfoot is President of the Association of Iron & Steel Electrical Engineers and will preside at the 25th Convention and Exposition being held in Pittsburgh, June 17-21, 1929.

The Value of Efficient Service Departments to the General Manager

By C. S. PROUDFOOT*

Shrewd minds are busily engaged with a multiplicity of problems arising from the tenseness of competition prevalent in practically every line of industry today. The hue and cry is for increased production, for it is through volume alone that costs can be lowered. Likewise, there is a concerted effort to discover principles for the basis of a more scientific and more permanent management of industry. Every phase and angle of industry is receiving the most careful scrutiny, to determine ways and means of greater output. Beyond this, there has always been the desire to effect better industrial relations.

Let us first consider the underlying precept of volume production; not its commercial or competitive character, but its industrial significance. What does it mean to the plant, and what is to be done in the plant, about it? Essential as it is that we strive for increased production, we must not lose sight of the fact that profitable production has its foundation in the establishment of an efficient industrial structure, under intelligent, scientific management.

The whole matter, therefore, devolves upon the General Manager; and it is of vital importance that he surround himself with the finest available, highly trained engineers and assistants, men who are themselves infinitely efficient as well as leaders of men; for, without the co-ordinated co-operation of these under-executives, the General Manager cannot hope to succeed, even in the perfunctory development of the enterprise.

The General Manager, as chief executive, is primarily responsible for the successful direction of the entire business. He is charged with the organization and co-ordination of the service departments. He must see that the various department heads function in harmony. He cannot afford to devote much of his valuable time to concentration on the details and variable elements of the institution. He must not only have a clear perspective of the trend of the industry as a whole, but he must also have a thorough insight of the status of his own entire organization, so that in an emergency he may be in a position to take in hand the smallest function. Too, he must be big enough to decide fairly and promptly on matters both momentous and comparatively inconsequential. Generally speaking, the General Manager must have his own business well under control, and at the same time know just what is going on in the whole industry.

Therefore, if the chief executive must keep his fingertips on the pulse of the entire industry, he must delegate the supervision of a tremendous amount of detail, and much of the executive routine, to his department heads—the thoroughly trained engineers and assistants; and every detail that he wisely delegates, allows him just so much more time to study the more important development of the whole enterprise.

There can be no doubt as to the value of efficient service departments to the General Manager, if they relieve him of the pressure of routine. The heads of these departments must be both leaders and thinkers, rather than drivers. These department heads must not only be thoroughly efficient personally, but they must cultivate among their workers a high order of efficiency. They must be of inquiring and scientific mind, and analytical of temperament, men who can see the need of change, think accurately, and formulate plans to be submitted to the General Manager, for the effective installation of equipment and methods, required by that change. This, of course, is the ideal arrangement, wherein the chief executive has merely to study the merits of such proposals, and either improve upon them or reject them, but it is indeed very fortunate that a wide range of administrative duties are now being delegated to engineers, as men of scientific training.

Consider for a moment the captain of a great vessel. Figuratively, the captain is the helmsman, directing the progress of his ship; avoiding the reefs and shoals. Practically, however, the captain is a very practical and efficient executive, with only a few essentially executive duties to demand his attention. Not by the wheel, unless it be an emergency, but by the pressure of a button, or by word of mouth, the captain directs his ship. He is concerned more with the condition of the sea; more with the course he has charted; with the speed of his vessel; safe in the knowledge that his officers are highly trained men: who in turn function efficiently, because they have cultivated efficiency among their subordinates; every man aboard ship working in unison and harmony.

Among the many qualifications that enter into the capacity of the general manager, is the quality of the detached point of view. He must not make the mistake of standing always at the wheel, in fact, he must delegate that as much as possible; he must be free from details. He must study his own institution and his industry from afar. He must study in perspective the trend of his industry and its competitive nature, to foresee, if possible, the changes that must take place in a constantly changing world. Sometimes, it seems surprising that a general manager can give a quick and accurate decision on a proposal even before it is fully related; but that is simply because he has viewed the whole scheme of his industry in perpective, and keeps in constant touch with its changes; because he has charted his course and knows where he is going, and why.

It is absolutely essential that the general manager has opportunity for detached analysis of his business; that he maintain a generous margin of safety against fatigue and exhaustion, both of mind and energy. So it is that the wise and successful chief executive employs expert assistance, and never depends solely upon his own efforts. He thus frees himself for the more important development of the whole enterprise.

*President, Association of Iron & Steel Electrical Engineers, Genl. Mgr., Vanadium Corp. of America, Niagara Falls, N. Y.

OFFICIAL CONVENTION AND IRON

AUSP

ASSOCIATION OF IRON & STE

JUNE 17, 18,

WILLIAM PENN HOTEL,

MONDAY, JUNE 17TH

9:00 A. M.—Registration, Main Lobby, Wm. Penn Hotel. Chairman, Mr. Russell Shepherd, Electrical Engineer, A. M. Byers Company, Pittsburgh, Pa.

9:30 A. M.—Business Session, Membership Invited; The Lounge on the Mezzanine Floor.

Chairman, Mr. C. S. Proudfoot, Manager of Works, Vanadium Corporation of America, Niagara Falls, N. Y.

TECHNICAL SESSIONS

Electrical Engineering Division

The Lounge on the Mezzanine Floor

Chairman, Mr. C. S. Proudfoot, Manager of Works, Vanadium Corporation of America, Niagara Falls, N. Y.

10:00 A. M.—"Electric Welding," by Electric Welding Committee. Chairman, Mr. S. S. Wales, Chief Elect. Engr., Carnegie Steel Company, Pittsburgh, Pa.

11:00 A. M.—"The Use of Moving Pictures to Illustrate the Generation of Involute Gearing and the Use of Moving Pictures and Polarized Light as a Method of Studying Gear Stresses," by Mr. W. H. Himes and Mr. R. V. Baud, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

12:30 P. M. Informal Luncheon. Italian Dining Room. Main Lobby

Members, Guests and Exhibitors Invited.

SAFETY ENGINEERING DIVISION

Italian Dining Room **Main Lobby**

General Chairman, Mr. C. L. Baker, Management's Repr., Bethlehem Steel Co., Johnstown, Pa.

2:00 P. M.—"The Incorporation of Safety Into Electric Station Design," by Mr. V. R. Bacon, United Engineers and Constructors, Philadelphia, Pa.

SPECIAL FEATURE

Official Opening of The Iron & Steel Exposition

7:30 P. M. **Main Lobby** **William Penn Hotel**

A Voice Controlled Electric Locomotive—Main Lobby, Wm. Penn Hotel.

INFORMAL RECEPTION

9:00 P. M. **Italian Dining Room** **Main Lobby**

Chairman, Mr. A. A. Stewart, Elec. Engr., Pittsburgh Steel Company, Monessen, Pa.

Features, Entertainment, Dancing. Members, Guests, Exhibitors and Their Ladies Invited.

TUESDAY, JUNE 18TH

SPECIAL FEATURE

ENGINEERING BREAKFAST

8:30 A. M. **Italian Dining Room** **Main Lobby**

All Engineering Divisions Invited, Exhibitors, Guests and Ladies.

TECHNICAL SESSIONS

Electrical Engineering Division

Italian Dining Room **Main Lobby**

General Chairman, Mr. F. W. Cramer, Chief Elect. Engr., Republic Iron & Steel Co., Youngstown, Ohio.

9:30 A. M.—"Anti-Friction Bearings for Mill Type Motors," by Special Committee on Bearings, Chairman, Mr. F. D. Egan, Elec. Engr., Bethlehem Steel Co., Lackawanna, N. Y.

11:00 A. M.—"Electric Heating," by Electric Heat Committee, Chairman, Mr. Geo. H. Schaeffer, Elec. Engr., Carpenter Steel Co., Reading, Pa.

11:45 A. M.—"Electric Developments in the Iron and Steel Industry," by Electric Development Committee, Chairman, Mr. Walter H. Burr, Elec. Engr., Lukens Steel Co., Coatesville, Pa.

COMBUSTION ENGINEERING DIVISION

The Lounge—Mezzanine Floor

General Chairman, Mr. Martin J. Conway, Fuel Engineer, Lukens Steel Co., Coatesville, Pa.

Chairman for Tuesday Combustion Engineering Meeting, Mr. L. C. Edgar, Chief Engr., Carnegie Steel Co., Edgar Thomson Works, Braddock, Pa.

9:30 A. M. —"Steam Generation and Utilization," by Mr. L. C. Edgar, Chief Engr., Carnegie Steel Co., Edgar Thomson Works, Braddock, Pa.

10:00 A. M.—"Some Results of Boiler Water Conditioning," by Mr. R. E. Hall, Hall Laboratories, Inc., Pittsburgh, Pa.

11:15 A. M.—"Efficiency versus Economy," by Mr. H. G. Ebdon, Combustion Engineering Corp., New York, N. Y.

TUESDAY AFTERNOON

1:00 P. M.—A. I. & S. E. E. Ladies' Bridge Luncheon, Keystone Athletic Club, Pittsburgh, Pa.

WEDNESDAY, JUNE 19TH

TECHNICAL SESSIONS

Electrical Engineering Division

The Lounge on the Mezzanine Floor

General Chairman, Mr. F. W. Cramer, Chief Elect. Engr., Republic Iron & Steel Co., Youngstown, Ohio.

10:00 A. M.—"Electric Departmental Organization," by Shop Practices Committee, Chairman, Mr. J. J. Booth, Elec. Engr., National Tube Co., Gary, Ind.

10:45 A. M.—"The Selection of Electric Equipment," by Mr. L. A. Umansky, General Electric Company, Schenectady, N. Y.

PROGRAM
AND STEEL EXPOSITION
ICES
EL ELECTRICAL ENGINEERS
19, 20, 21, 1929
PITTSBURGH, PA.

COMBUSTION ENGINEERING DIVISION

Crystal Room—Parlor Floor

General Chairman, Mr. Martin J. Conway, Fuel Engineer, Lukens Steel Co., Coatesville, Pa.

Chairman for Wednesday Combustion Engineering Meeting, Mr. Walter Flanagan, Special Engineer, Carnegie Steel Co., Pittsburgh, Pa.

10:00 A. M.—Report of the Gas Utilization Committee, by Walter Flanagan, Chairman, Special Engineer, Carnegie Steel Co. With special items by J. W. Jones, A. G. Witting, J. C. Hayes, W. E. Bisler.

10:30 A. M.—"The Combustion of Liquid Fuel," by Mr. R. C. Vroom, Asst. Chief Engr., Peabody Engineering Co., New York, N. Y.

11:15 A. M.—"Economizers," by Mr. Walter Keenan, Jr., Consulting Engr., Foster Wheeler Corp., New York, N. Y.

WEDNESDAY MORNING

10:00 A. M.—A. I. & S. E. E. Ladies' Sight Seeing Trip in Pittsburgh and Environs.

THURSDAY, JUNE 20TH

TECHNICAL SESSIONS

Electrical Engineering Division

The Lounge on the Mezzanine Floor

General Chairman, Mr. F. W. Cramer, Chief Electrical Engineer, Republic Iron and Steel Co., Youngstown, Ohio.

10:00 A. M.—"Portable Electric Tools," by Portable Electric Tool Committee, Chairman, Mr. J. S. Murray, Chief Electrical Engineer, Follansbee Bros., Follansbee W. Va.

10:20 A. M.—"Grounding Portable Electric Tools," by Mr. W. M. Runyon, Crouse Hinds Company, Syracuse, N. Y.

10:45 A. M.—"Some Methods of Best Utilizing Electrification in the Steel Industry," by Mr. G. E. Stoltz, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

COMBUSTION ENGINEERING DIVISION

Crystal Room—Parlor Floor

General Chairman, Mr. M. J. Conway, Combustion Engineer, Lukens Steel Company, Coatesville, Pa.

Chairman for Thursday Combustion Engineering Meeting, Mr. F. E. Leahy, Fuel Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.

10:00 A. M.—"Some of the Business Aspects of Furnace Manufacturers," by Mr. F. W. Manker, Great Lakes Steel Company, Ecourse, Michigan.

10:45 A. M.—"Gas Producers," by Mr. F. E. Leahy, Fuel Engineer, Youngstown Sheet and Tube Co., Youngstown, Ohio.

11:15 A. M.—"The Application of Pulverized Fuel in Industrial Furnaces," by Mr. W. O. Renkin, Combustion Engineering Corporation, New York, N. Y.

THURSDAY AFTERNOON SPECIAL FEATURE

INSPECTION TRIP

Jones and Laughlin Steel Corp., Aliquippa Plant, Aliquippa, Pa. All Engineering Divisions, Guests and Exhibitors Invited. Train leaves 1:00 P. M. Daylight Saving Time P. & L. E. Station, South Side. Special priced tickets to be sold on special train. For this Inspection Trip the special train must be used; coaches will be used for transportation in the plant. Will return to Pittsburgh about 5:30 P. M.

THURSDAY EVENING

FORMAL RECEPTION AND DINNER DANCE

Featuring

MR. RICHARD CROOKS, Celebrated Operatic Tenor,

For the Dancing

DON BESTOR AND HIS

VICTOR RECORDING ORCHESTRA

Chairman, Mr. W. E. Miller, Electrical Engineer, Bethlehem Steel Company, Cambria Works, Johnstown, Pa.

Italian Dining Room **Main Lobby**

FRIDAY, JUNE 21ST

TECHNICAL SESSIONS

Electrical Engineering Division

The Lounge on the Mezzanine Floor

General Chairman, Mr. F. W. Cramer, Chief Electrical Engineer, Republic Iron and Steel Co., Youngstown, Ohio.

10:00 A. M.—"A Lighting Survey of Steel Plants," by Mr. S. G. Hibben, Westinghouse Electric & Mfg. Co., New York, N. Y.

10:45 A. M.—"Time Current Control for D. C. Motors," by Mr. D. C. Wright, Electric Controller & Mfg. Co., Cleveland, Ohio.

IRON AND STEEL EXPOSITION

Monday	opens at 1:30 P. M., Closes at 9:30 P. M.
Tuesday	opens at 1:30 P. M., Closes at 9:30 P. M.
Wednesday	opens at 1:30 P. M., Closes at 9:30 P. M.
Thursday	opens at 9:30 A. M., Closes at 12:30 A. M.
Friday	opens at 1:30 P. M., Closes at 9:30 P. M.
Friday Evening	— Maintenance Department Employees

Efficiency

By R. B. GERHARDT*

The steel plant electrical department efficiency as far as our Association members are concerned is generally thought of as relating to economical power generation, transmission, and distribution; the highest developed motor and control application to each unit drive; the best practical lighting installations; a full line of principal spare parts for all important machinery, as well as a complete departmental organization with shops having a full complement of equipment for properly maintaining plant apparatus. With these points in mind we attempt to measure this efficiency in terms of

1. Unit cost of electrical energy,
2. Power consumption per unit of product,

R. B. GERHARDT

3. Proportion of total time actually operated by departments without electrical delay of any nature,
4. Capital invested in electrical inventories, and
5. Cost of repairs and maintenance.

The last two of these items as viewed from the plant management's standpoint should receive more attention from the electrical staff with a view toward bringing them up on a par with the first three. Many of our electrical men feel that their departments have reached a very high degree of efficiency when the cost of generating a K. W. H. and the K. W. H. per ton of product are showing favorably, and the delay sheets show no electrical trouble in the mills; but let them investigate the amount of capital tied up in spare parts and inventories, and the cost of maintaining the plant electrical equipment; then they may have a sad awakening, for to secure such a showing these items are in all probability quite top heavy. There is a certain economical balance representing best practice. I would suggest as a measure of efficiency in these points that a figure be determined for each plant, and if it is desired for each department, representing first the capital invested in spare parts and inventories, and second, the total electrical repair and maintenance expense including overhead, both of these amounts figured per K W H consumption per HP of connected load. A comparison of such figures between plants will soon show up the most efficient and best managed electrical department.

It is a very comfortable feeling to know that spare parts and inventories cover every possible emergency in the plant, yet the plain economics of each individual situation dictate to what extent each should be protected. We all know that standardization of equipment is the greatest factor tending to minimize investment in spares, but too frequently we sacrifice this standardization for reasons that are not economically sound.

As regards repairs and maintenance the reduction of this expense in our plants presents a very fertile field for the ingenuity of the electrical staff to make a fine showing. We must be on the alert to analyze every apparatus failure and if possible anticipate this failure so that conditions causing same can be corrected before failure occurs. To accomplish this we know that proper inspection is necessary, but the troubles are not always corrected and in many cases we are too hasty in condemning surrounding conditions or some equipment in its entirety when only a detail is at fault.

I believe that the greatest showing can be made by closer study of the actual cost of making repairs, by taking advantage of all kinks and short cuts and using the best materials possible obtainable, by more carefully planning the work, and by placing the maximum possible amount of this work on contract or piece rate basis under rigid inspection.

*Asst. Genl. Mgr., Bethlehem Steel Co., Steelton, Pa.

New Methods and Practices in Selling Steel

By J. W. DONNER*

Andrew Carnegie is reputed to have said: "The Steel Business is either a feast or a famine." Such indeed has been its history. With the great War came great feasting, and since 1920, until recently, there have come leaner years. With competititon very keen during those lean years, the battle to reduce costs has been valiantly waged.

Here the Iron and Steel Engineer has been called upon to find new ways of doing the old things cheaper. Practices long established have been changed, equipment old and new discarded for better and more efficient, men and materials have been speeded up to a pitch never before reached in the industry. Running along in this high gear the industry has broken its monthly and quarterly ingot production records in the first quarter of 1929 and operated at 103% of capacity during March. And still demand for iron and steel continues far above the levels of recent years.

J. W. DONNER

Such facts make pleasant reading to those who have struggled through the recent famine. It would appear that we are now in an era of feasting once again. The law of supply and demand, the simple and fundamental truth behind all industries, shows us that the over-production built up by the war demand has now been caught from behind by the demand of a constantly growing and prosperous country.

But the recent heavy demand for steel cannot be expected to be continuous. At this writing (late April) signs have appeared of a seasonal slowing up. Men of the steel industry should bear in mind two things; in the first place with the industry entering a more prosperous era, steel operating departments and steel engineers should not lose their keen point of view and be lulled into that complacent feeling that their plants are, after all, in pretty fine shape and that they can rest on their oars for awhile just filling orders and maintaining operation. Keen competition stimulates cost cutting and conversely less keen competition removes the edge from that cost cutting keenness. The most successful companies are operated by men who do not lose their appetite for lower costs.

Secondly, steel salesmen should recognize this seasonal let-up and not attempt to maintain their full operating schedules at the sacrifice of prices. To do so may seem profitable at the moment but when analyzed appears manifestly unsound. Steel salesmen, as a whole, however, have followed just such cut-throat practices in the recent past and the warnings and entreaties of the recognized leaders of the industry, not only prove this fact but emphasize the folly of it. (In fact the salesmen behind some of these recognized leaders have themselves been guilty of these practices.) There are customs and practices followed by steel salesmen dating from premodern times and an attack of sales problems by methods more modern and progressive would be of infinite value to the industry. Steel operating departments, with the exception of a few of the older and more self satisfied, have been quick to follow and adopt new methods and new practices. It would be well for sales departments to follow their example and try to determine what can be accomplished in their spheres along more modern trends. Sales stimulation has been accomplished in other metal and allied industries—why not in the Steel Industry?

*Vice President, Donner Steel Co., Buffalo, N. Y.

Engineering in the Steel Industry

By W. H. WARREN*

Everyone who is in any way connected with the steel industry's problems of the present day is vitally concerned with the subject of preventable losses. Broadly, as well as definitely considered, all of the questions of today depend for their ultimate solution upon a thorough and exhaustive analysis of preventable losses. The loss incurred through inefficient and insufficient production is, from our particular point of view, the greatest preventable loss in the steel industry today, and we are firmly convinced that waste of effort cannot be checked and real industrial plant efficiency attained until we thoroughly recognize the importance of the engineer in our scheme of management. The industrial executive must provide the opportunities and recognize the pressing necessity in his business of developing engineers who are vitally interested in the cost of operation as well as the cost of engineering. Heretofore, full scope for initiative and a voice in the councils of the management have not been given to such men. In this world we usually get what we pay for. Harking back to the "good old days" our engineers "did as they were told" with the result that plant improvements were developed rather than originated by the various engineering departments. While a certain amount of suggestion will always come from the field, and represents a healthy condition, the engineers activity must not be confined to following instructions and adjudicating between competing builders of equipment so that his company may receive what is best for their conditions at the desired time.

The engineer is much too isolated at present. He should form association of his fellows, at least among those in his own branch of engineering. They should meet and discuss, as informally and as frequently as possible, their various problems of operation and their experiences with new equipment. Members of these associations should submit problems for discussion, not to take the form of papers, but of free talks of a confidential nature among themselves. A movement of this sort should receive every encouragement from industrial executives. Why should men operating similar plants each have to make the same original experiments and usually the same mistakes? The day of industrial secrets is practically over. There is more to be gained from a free exchange of experience than from special little tricks, jealously guarded, as in former days. Industries, to prosper, must broaden both their knowledge and their sympathies. The so-called good old days have passed when the individual plant owner could, and often did, defy everyone else in the same industry and follow his independent course, neither giving nor receiving information. Manufacturers in other countries have learned that a free interchange of technical experience pays all concerned. A large share of the recent rapid development of the steel industry has been due to the partial adoption of this plan and to the free interchange of experience, but we have not gone far enough.

There is another point. Competition forces the producer not only to do his best with his own plant, but inevitably to co-operate with others.

The far-sighted executive of today does not hesitate to invest money in engineering brains. The best solutions to his problems are not to be found by the men of mediocre training or experience. Engineers are selected who are experienced and competent in industrial practice.

The Association of Iron and Steel Electrical Engineers, with its various Divisions covering every engineering activity in the steel industry, cannot do other than broaden the knowledge and experience of the members who are actively interested, thereby benefiting the engineer, the industry, and ultimately the consumer.

*Genl. Supt., Lukens Steel Co., Coatesville, Pa.

Ramifications

By F. W. CRAMER*

The coming convention in Pittsburgh brings our annual meeting back again to the city in which our Association was founded. Once more we will pay homage to the district that for many years has been recognized as the heart of the iron and steel industry and the leader in many of the modern innovations of the art. Although it has only been two years since we had our annual meeting in Pittsburgh, those who are familiar with the local district mills realize that even in this short time, many changes have been made.

If we are allowed to refer to our first meeting here some twenty years ago, we find that the cause of the gathering was to secure a mill motor which would stand up under the duties of making steel. After this was accomplished, the thought turned to the mill cranes and resulted, eventually, in our standard crane specifications. Control and converting equipment were other subjects that were given much thought with a view of obtaining equipment that would stand up under the rough mill usage and give service twenty-four hours per day. The

*Chief Elec. Engr., Republic Iron & Steel Co., Youngstown, O.

great problem of accident prevention also had a part in these early meetings and we are proud of the fact that it still occupies a major position in our activities today.

As these major problems became solved, it was only natural to look for new fields to conquer and in time the large main drives with their automatic control occupied our thoughts. It required several years to prove to the industry the true value of main drive motors, both as an economical investment and a reliable piece of machinery. Today I do not believe that the large electrical main drives need to be argued about, as the problem has been reversed and the mill contemplating a steam engine installation has the burden of proof to submit.

Another subject that was given serious thought for many years was the purchase of power. It was a long while before the Public Service Companies realized the advantages of a steel mill load to such an extent as to make rates that were attractive to the industry. Perhaps the super power stations and high voltage "hookups" among the large companies were of great assistance in their being able to handle our loads with the high degree of continuity of service we demanded. Today we find many of our large steel companies buying power from the larger public service companies and also having large generating stations of their own. The rapid growth in the size of the steel mill generating stations and the immense concentrations of power that it is possible to receive from the Public Utility Companies has brought about a serious problem in transmission and switching equipment in our mills and today this subject has assumed the place of prime importance.

With the peculiar situation of a huge 6600 volt power consumption within a small area, the magnitude of short circuited currents in time of trouble often exceeds the capacity of the equipment. All of the older steel companies are aware of this condition and are trying to rebuild or replace their switching apparatus with equipment that will withstand the enormous electrical stresses they are liable to be subjected to. The problem involves speculation as to the future requirements in the mills as none of us care to revamp our systems and find them inadequate again in a few years. The study of transmission systems and short circuit currents is perhaps the most important subject before the steel mill electrical engineers today.

We know that one by one the various mills will find the solution of their own system and then other important lines of development will follow. The Association will serve as it always has done as the instrument for recording the developments of the industry.

Our technical papers in the coming convention should be of interest to every member. The number of subjects that had to be given a place on the program was so great that those dealing with combustion were scheduled for a separate series of meetings in order to give them a proper allotment of time. With all activities under one roof, the Association has made it convenient for attendance at the technical sessions. The high grade of papers to be delivered on important subjects should induce the best attendance ever, which in turn not only encourages the authors, but also results in more extensive discussions.

The 1929 Convention Technical Sessions have been arranged to bring out the newest and best thought in the steel mill electrical problems. Your attendance at these meetings will help in making them the best we have had.

The Electrical Superintendent

By R. M. HUSSEY*

In the larger industrial plants, especially in the steel industry anyway, the electrical superintendent has come to be a man in whom are combined some of the predominant characteristics of men in lines of work outside the electrical engineering profession; at least the electrical superintendent should have developed into such a man by this time if he is to be called a superintendent.

First of all, he is a technically trained man, yet not so bound up in the theories of electrical engineering that he cannot strike a working balance between theory and practice. He must be technically trained enough to understand the plans, designs and propositions of the theoretically inclined electrical engineer, and yet practical minded enough to put the products of the electrical engineer in such shape that they will best suit certain working conditions.

He is an organizer. He must have a natural bent for getting together an organization of engineers, assistants, foremen, squad leaders, and a corps of loyal, conscientious workers; get routine work so lined up that it will be done smoothly and surely; and have his men trained to exercise good judgement and act on their own initiative.

He is a practical man; a man with technical training backed up by practical experience, usually in the test course of some electrical machinery manufacturer and in the employ of some central station company or some industrial plant as lineman, wireman, tester or operator. He has attained his present position as superintendent through successive promotions.

He is the head of a Service Department and, therefore, co-operates with other department heads in carrying on operations at highest rate of production, yet at the lowest possible cost. He is ever ready to depart from old established customs to try something new that will increase production or decrease costs. He has an eye for business also in that he tries to meet all his customers' requirements (the requirements of other departments) with repair part stocks adequate for uninterrupted operations, yet with as small an inventory as possible. He watches

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*Second Vice President, Association Iron and Steel Electrical Engineers.

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market conditions as closely as possible to anticipate price changes, to keep active stocks coming along as needed and turning over as much as possible, and also to take advantage of standard package or quantity lot prices.

He is a man who maintains an acquaintance with men in other plants and industries and keeps posted on progress of things most pertinent to his line of work.

He is not a sales engineer, but he is ever on the alert to further the interests of his company in the sale of their product. He is helpful in this way by bringing about changes in designs or making substitutions in the manufacture of electrical machinery, to use his company's products wherever possible.

He is a safety engineer; not the safety engineer but the plant safety engineer's helper in every way the safety engineer is concerned with things electrical.

H is a man who has a well defined place in the scheme of things and can, by being all that is said of him above, or more, be a real asset to his company, and enjoy the right to be called the Electrical Superintendent.

The Association Magazine

By MARTIN J. CONWAY*

Our Association organ, the IRON AND STEEL ENGINEER, is being prepared to meet that need of the Steel Industry which calls for a single magazine of moderate size which will cover the whole field of the primary service departments, Electrical, Mechanical, Fuel and Safety.

The Iron and Steel industry has developed so rapidly within the last few years, and the literature has

MARTIN J. CONWAY

become so voluminous, that it is a matter of extreme difficulty to decide exactly what our members need most, and, sufficient credit cannot be given to those individuals and organizations who contribute so freely to this magazine.

The IRON AND STEEL ENGINEER cannot serve the purpose intended unless it is thoroughly read, and, those papers and articles having an important relation to our job should be re-read.

Tourists in foreign lands all too frequently gather nothing but blurred impressions as they dash from one point to another. The true traveler remains in one place long enough to gain the enduring treasure of a real understanding. The tourist who has "done" a place seldom cares to go back. The wiser traveler returns with increased pleasure.

As with travel, so with reading. Dividends of satisfaction from reading bear little relation to the "mileage covered" in books and magazines. The important consideration is how much has been absorbed along one's reading journeys. Most assuredly, our members will find articles in the IRON AND STEEL ENGINEER of such significance as to be worth re-reading.

Life is hurried, and, in consequence, one's reading is hurried, too. What is read is not always thoroughly "inwardly digested." For this there should be reflection, cogitation, and re-reading after an interval. For only by a thorough understanding of the case presented by the author can we discover the theme around which his paper has been written.

The IRON AND STEEL ENGINEER is published in an attempt to disseminate knowledge and information on all matters relating to the economical application of electricity and fuels in the steel industry and of necessity some of the articles and papers, do and will, call for a certain amount of criticism, but we must be fair in our criticism. Criticism is either constructive or destructive; fair criticism means progress, unfair criticism indicates stagnation. Today every person and almost everything is subject to criticism which unfortunately often resolves itself into mere abuse and this results in retarding progress, not only in public life but also in industrial and scientific fields of activity. Some of the unfair criticism is due to purely personal interest of a material nature. Such criticism however, as a rule fails to produce serious consequences, but the criticism which arises from prejudice and lack of vision and often of knowledge also, endangers constructive progressive movements at their birth and often retards their development. Criticism from the latter angle is more dangerous in an industry of established traditions like the Iron and Steel industry, than it is in other industries having a more fluid general outlook.

Change is always regarded suspiciously and tranquility is bought often at a sacrificial price.

This is peculiarly applicable to the industrial world and a study of industrial development during the last decade will serve to illustrate the point.

*Fuel Engineer, Lukens Steel Co., Coatesville, Pa.

Report of Electrical Development Committee, Association of Iron and Steel Electrical Engineers for 1928-1929

By W. H. BURR†

For a number of years, it has been customary to have presented during our National Convention a paper in which is given a brief description of the electric main roll drives installed during that year.

The January issue of most of the Engineering periodicals is now devoted largely to the developments which have taken place in the industries during the past year. Following this custom, the January issue of the "Iron and Steel Engineer" contained a description of the principal main roll drives which were installed in 1928. For this reason, only a small portion of this report will be devoted to description of the main roll drives installed during the past year,

W. H. BURR

the development along other lines, however, will be given as usual.

Each year, beginning with 1925, there has been published in the "Iron and Steel Engineer" a complete list of all main roll drives in United States and Canada which are motor driven including those as low as 300 HP. They are arranged according to size and also according to type of mill, but even then, it contains so much information that it is hard to comprehend.

One of the best known methods of creating an impression on the human mind is through the eye. Our schools are taking advantage of this and are using moving pictures as a means of education. High speed oscillographs have been developed which indicate by means of curves, made by projecting a beam of light on sensitized films, conditions that exist during lightning discharges.

Industry in all its branches is taking advantage of this fact and as a result operations and even conditions are now being pictured graphically. With this in mind, charts have been prepared which show the data which has been collected during these years in a form which we believe can be more readily understood.

The first of these charts shows the number of drives installed each year, beginning with 1905, and also a curve which indicates the total number of drives installed at the end of each year. During 1928, there were 171 electric drives installed, the greatest number so far in any one year. At the present time there are over 1600 electrically driven main rolls in the steel industry on which are installed over 2,000,000 HP in motors.

Chart No. 2 shows the number of horsepower in motors of 300 HP. or over installed each year and also a curve which shows the total horsepower at the end of each year. The year 1925 stands out very conspicuously, there being 265,000 HP in motors installed in that year alone. This is due, no doubt, to the fact that a number of new drives were installed on nearly all types of mills during that year.

The effect of the business depression of 1907 and 1911 are very clearly indicated. In fact in 1911, the poorest showing was made since this record was started. The effect of the war is easily seen in 1918 and the slump in business conditions in 1921 is very evident.

Charts have also been worked up which indicate the conditions that have existed each year in the various type mills. One of the first applications of motors to main roll drives was on plate mills. Chart No. 3 shows that 4,000 HP in motors was installed on plate mills as early as 1905. This chart differs materially from the others in that the application of motors on this type mill has been very irregular. The fact that no new drives were installed in 1928 is conclusive evidence that there are installed at the present time enough plate mills to supply the plate demands of this country. The effect of the wide strip mills on the plate business is perhaps another explanation of this condition.

Chart No. 4 shows conditions as they have existed in Blooming Mills, 1916 and 1925 standing out very conspicuously. Four of the leading steel manufacturers installed motor drives on Blooming Mills during the year 1925. Over 200,000 HP in motors are used to drive the blooming mills in the steel industry.

†Chairman, Electrical Development Committee. Elec. Engr., Lukens Steel Co., Coatesville, Pa.

Chart No. 5 covers the Bar and Billet Mill Drives. Practically all the main drives that were electrified during 1907 were Bar and Billet Mills. Today there is over 300,000 HP in motors on mills of this type.

From Chart No. 6, it is evident that the year 1926 saw the greatest increase in electric drives on Sheet Bar and Skelp Mills, 36,000 Hp in motors were installed on these mills that year, which is more than ¼ of the total horsepower installed on such drives.

alone 61,000 HP in motors. From Chart No. 10, it can be seen that this is twice as many as were installed in any other year.

Chart No. 11 covers Merchant Mills and indicates a fairly steady growth in number of horsepower in motors installed on this type mill. Merchant Mills rank third in total number of horsepower installed on main roll drives. 41 drives were installed during the year 1928.

It is very evident that there was a demand for rod

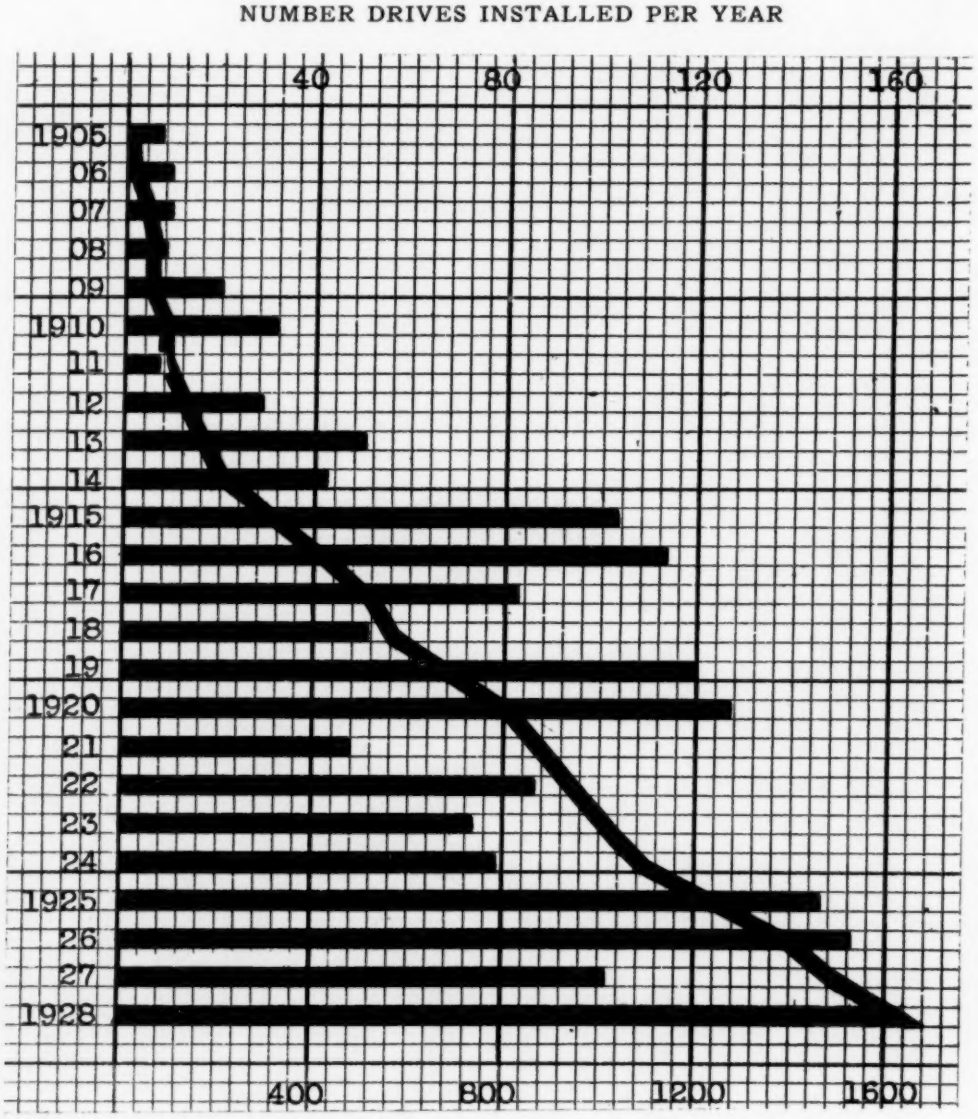


FIG. 1—Graphic Chart Showing Yearly and Total Number of Drives Installed on All Types of Mills.

Chart No. 7 indicates that between 1915 and 1920, Sheet and Tin plate mills were being installed in considerable numbers.

In Cold Mills, the year 1927 saw the greatest development as is indicated by Chart No. 8.

During the year 1927, 30,000 HP in motors were installed on Tube and Piercing Mills in the country. Chart No. 9 also shows that 21 mill drives were installed during that year, indicating very clearly the trend of steel business in this direction.

In 1924, there were installed on Structural Mills mills too during 1928 for Chart No. 12 shows a greater horsepower in motors installed that year than in any other year.

In going over these records, one fact cannot be overlooked and that is: The largest increase in horsepower installed on main rolls last year was on Strip Mills. 42 motors were installed representing over 50,000 HP in motors and of this number all but 4 were DC motors. This means that 25% of the total number of main roll drive motors installed last year were on Strip Mills.

As the type mill required to supply the demand for steel is changing, so the type motor used is also changing. A survey of the installations made reveals the fact that 58% of all the motors installed last year were DC motors and 42% were AC motors. It is also worthy of note that 23% of these motors were synchronous motors, 38 of this type representing a total of over 47,000 HP were installed last year. In 1913, a 500 HP synchronous motor was installed on a sizing mill. No others were installed until 1924 and since that time there have been installed 82 motors of this design, representing over 100,000 HP. Synchronous motors are being used on Bar and Billet Mills, Rod Mills, Merchant Mills, Strip Mills, and Rail Mills.

Only 1 AC speed set was installed during the year 1928 and when you recall that there have been 140 AC speed sets installed it is quite evident this drive is not as popular as it was at one time.

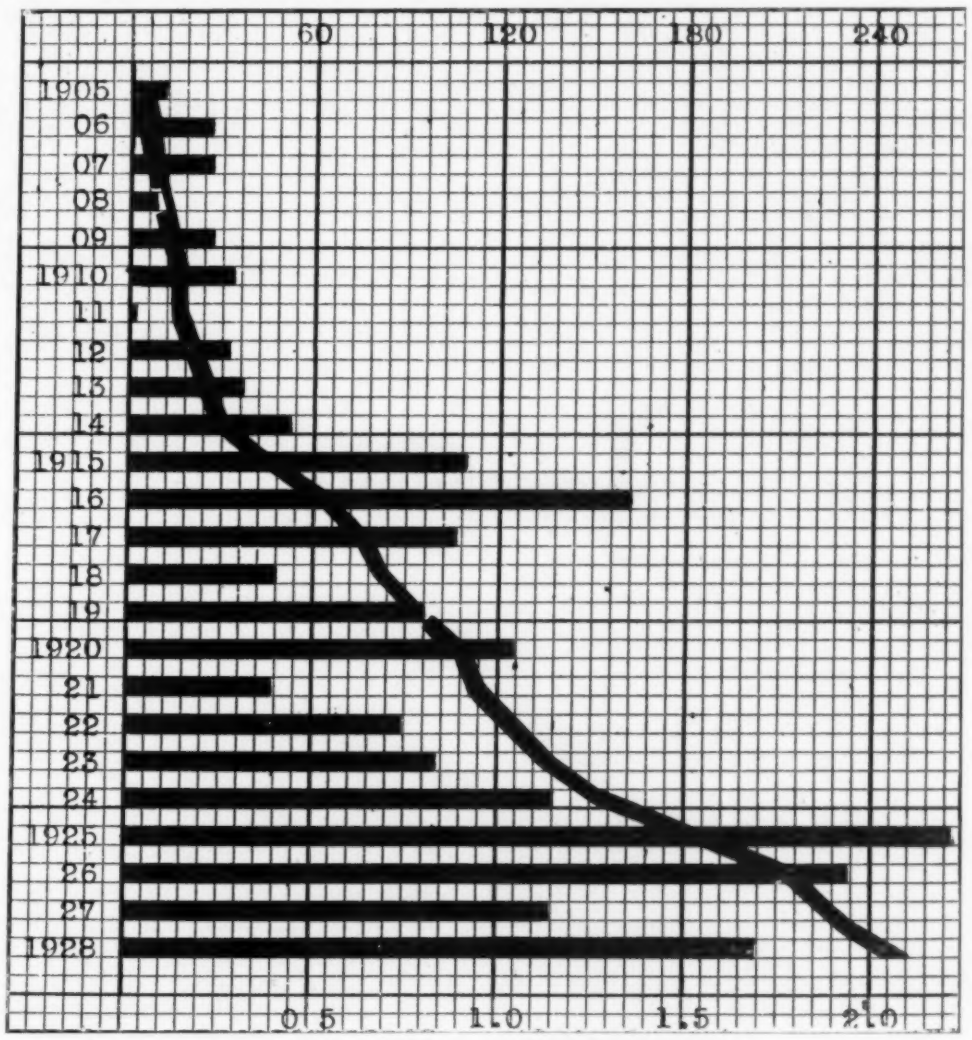
The use of DC motors is continually increasing and no doubt will, as long as our mill practice requires individual motors on each roll stand.

MAIN ROLL DRIVES

The first rolling mill ever built exclusively for fabricated electrical machinery parts has just gone into service. This quarter million dollar investment makes possible welded-structural machines of the largest dimensions. Red hot slabs emerge as hoops of steel, from 30 in. to 40 ft. in diameter, ready for welding. The mill rolls parts for all DC machines (7000 HP is about the maximum required), and rotors for slow speed AC machines up to 5000 HP.

At the far end of the room, the furnace door gapes open, a glowing strip of metal slides out, is transferred to the motor-driven roll table and hustled to the crimping press. One end of the slab lodges in the dies of the 1,000 ton hydraulic crimper, the big press slowly rocks to the left, and the slab moves forward again with a symmetrical curl in the leading end.

HORSEPOWER DRIVES INSTALLED PER YEAR
(Thousands)



Total Horsepower Installed.
(Millions)

FIG. 2—Graphic Chart Showing Yearly and Total Motor H. P. Installed on All Types of Mills.

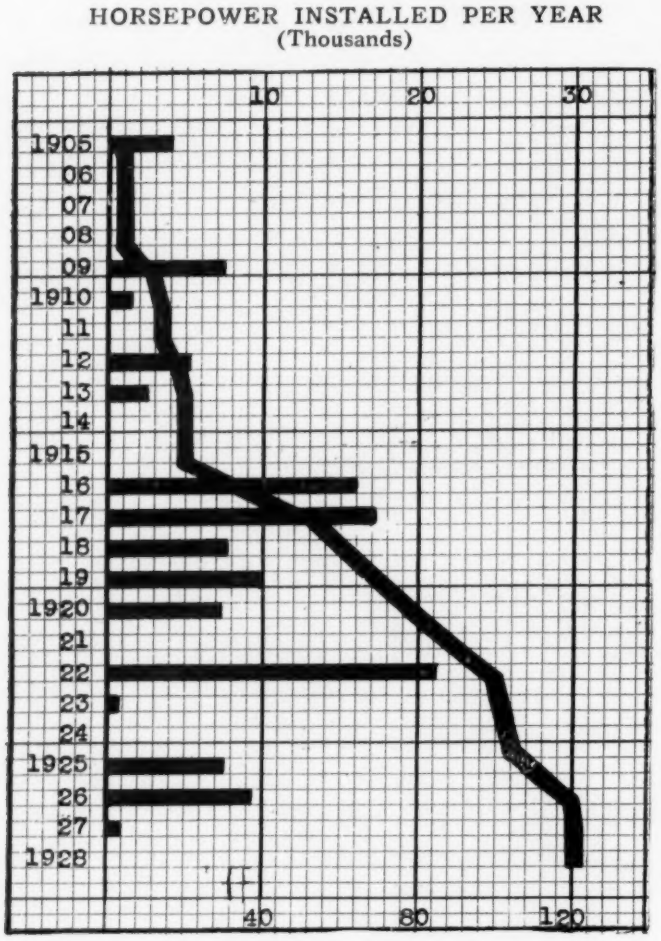


FIG. 3—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Plate Mills.

A similar curl appears in the trailing end as it leaves the crimper. The "pick-up" turns the slab on edge and it threads through the bend rolls. In the same way a piano is moved across a smooth floor, pipes on the floor roll along and support the bottom edge of the hoop as it is being formed. Shortly, a crane takes the ring to the shot-blast and it emerges with that clean surface so important to proper welding. Welders get to work, the gap in the rolled rig vanishes and an embryo motor or generator stands in view.

Naturally the building itself, housing the rolling mill, was constructed entirely by arc welding.

TURBINES

High Pressure Turbines

The rapid increase in the adoption of 1200-lb. pressure is indicated by the growth in capacity since 1923, when a 3,000-KW unit was first utilized. By the end of 1927, four units had been contracted for aggregating 27,000 KW, and during 1928, five additional units designed for 1200-lb. steam pressure with a total capacity of 186,000 KW were completed or under construction.

Single Cylinder Turbines

During the year the maximum size of 1800 RPM, single-cylinder turbines increased 10,000 KW to give a total of 75,000 KW. A unit of this size is being built for the Union Electric Light and Power Company for installation in the Cahokia Station at St. Louis. The steam conditions are 315 lb., 725 deg. F.

Equally notable, in the single cylinder turbine field, is a new unit for the Milwaukee Electric Railway and Light Company. This is an 1800 RPM turbine of 60,000 KW capacity. This unit is equipped with an oil governor of the impeller type. The rotor is the largest ever shipped completely assembled.

Tandem Compound Units

A 94,000 KW tandem compound unit, the largest completed unit of its type, was placed in service, and work was nearing completion on a 160,000 KW tandem compound and a 208,000 KW cross-compound unit, each representing the maximum capacity in its type.

Two Cylinder Cross Compound Units

Notable among large turbine-generator sets placed in service in 1928, is the 110,000 KW two-cylinder cross-compound unit for the Brooklyn Edison Company. Its rating is high, especially in view of the fact that it operates at 1800 RPM.

A reduction in the overall length of the rotor has been made possible by means of a special rotor construction in the low pressure turbine. The throttle steam pressure is 400 lbs. per sq. in. gauge. This would have been considered high a few years ago, but is a moderate pressure, according to present day standards.

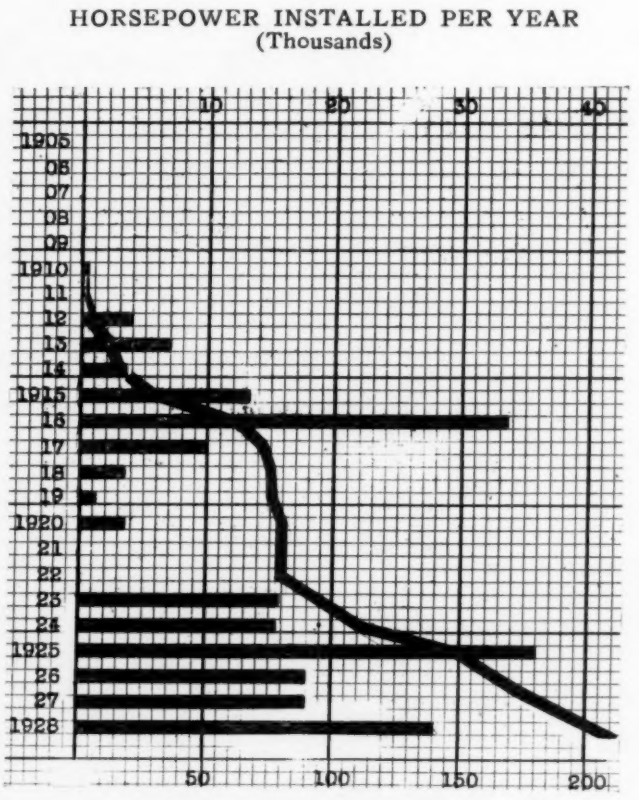


FIG. 4—Graphic Chart Showing Yearly and Total, Motor H. P. installed on Reversing Blooming Mills.

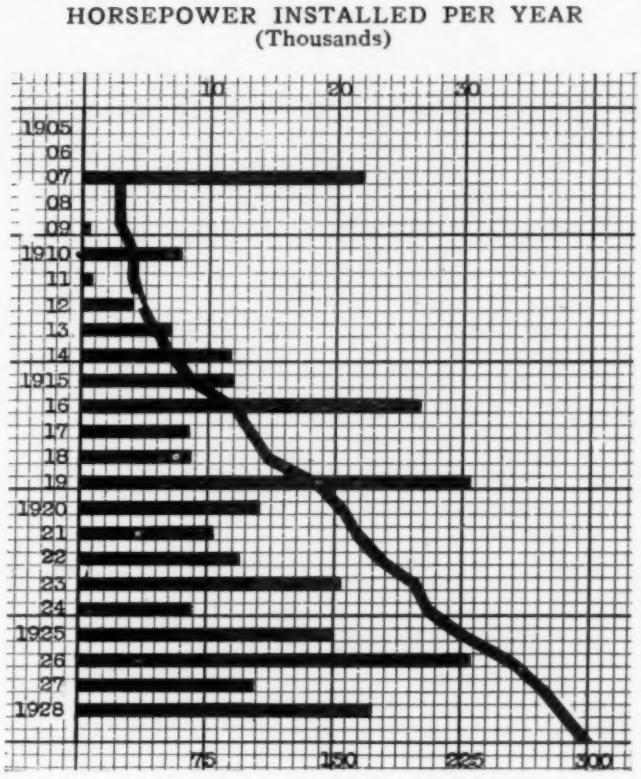


FIG. 5—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Bar and Billet Mills.

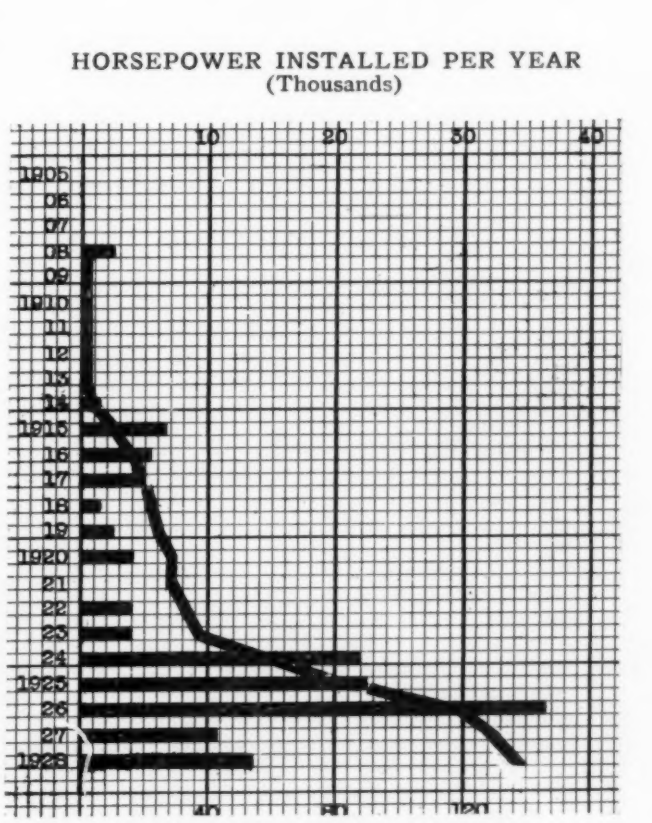


FIG. 6—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Sheet, Bar and Skelp Mills.

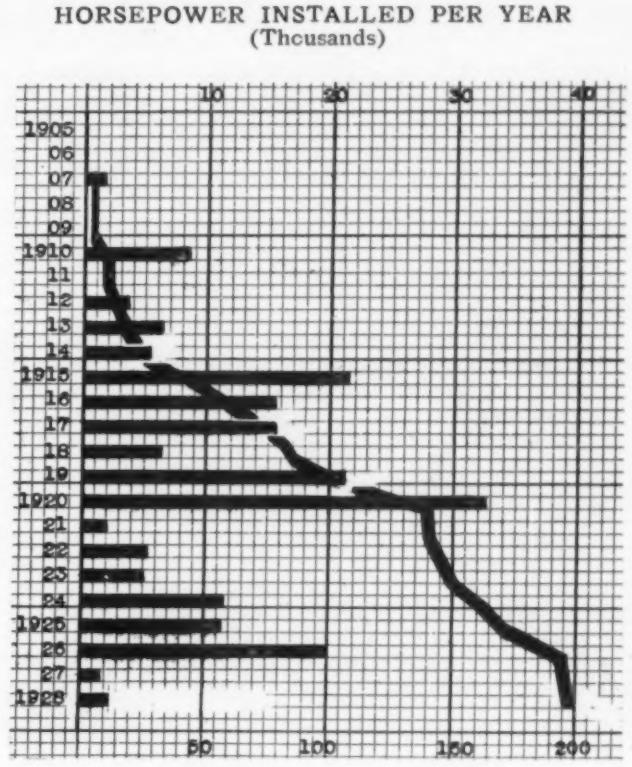


FIG. 7—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Sheet and Tin Plate Mills.

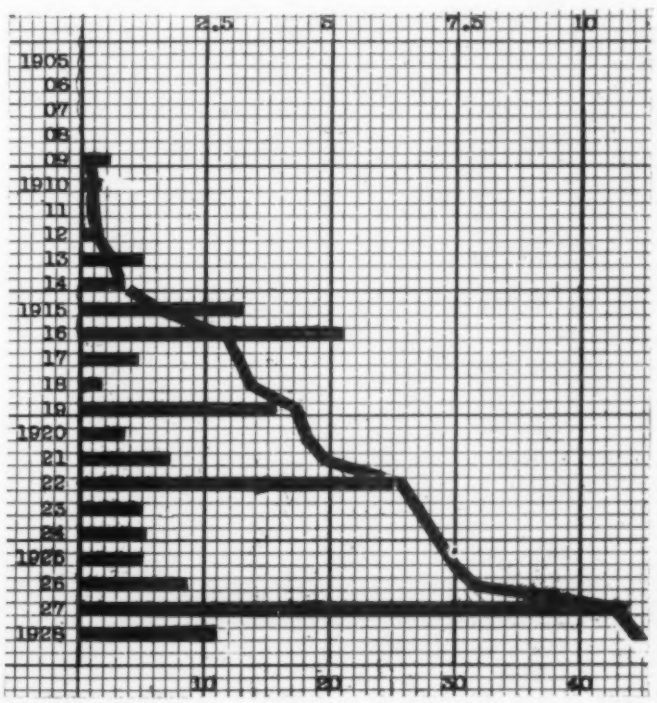


FIG. 8—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Cold Roll Mills.

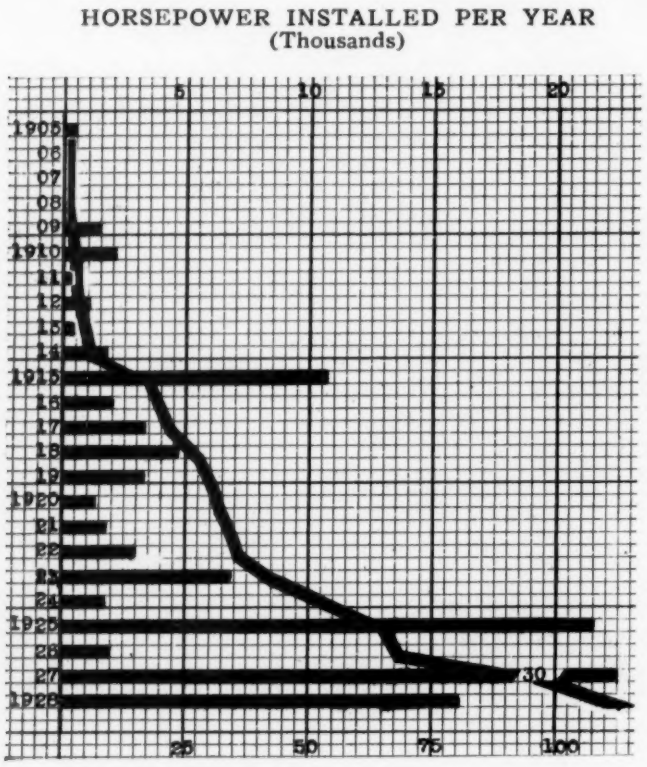


FIG. 9—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Tube and Piercing Mills.

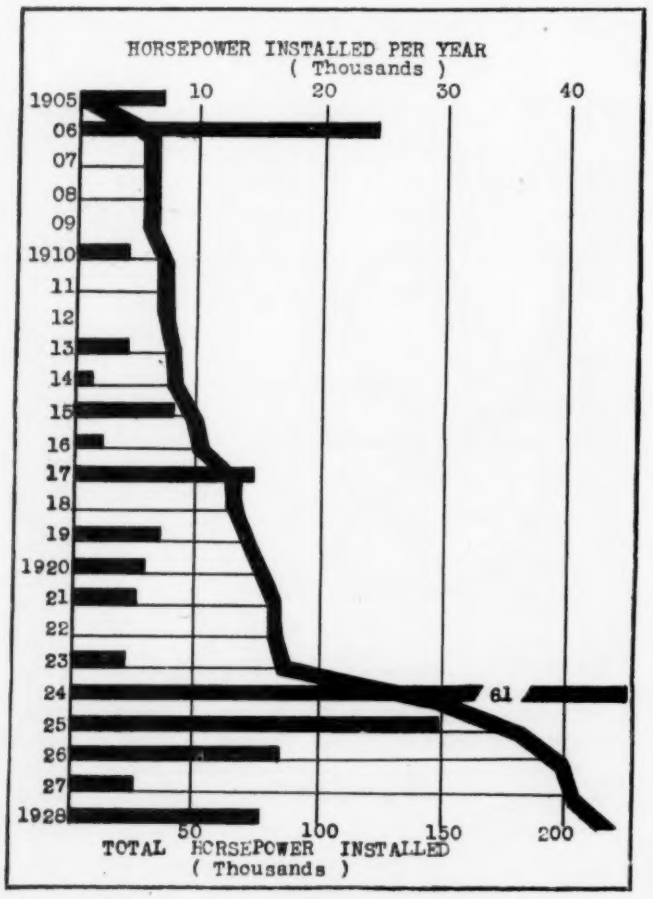


FIG. 10—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Structural Mills.

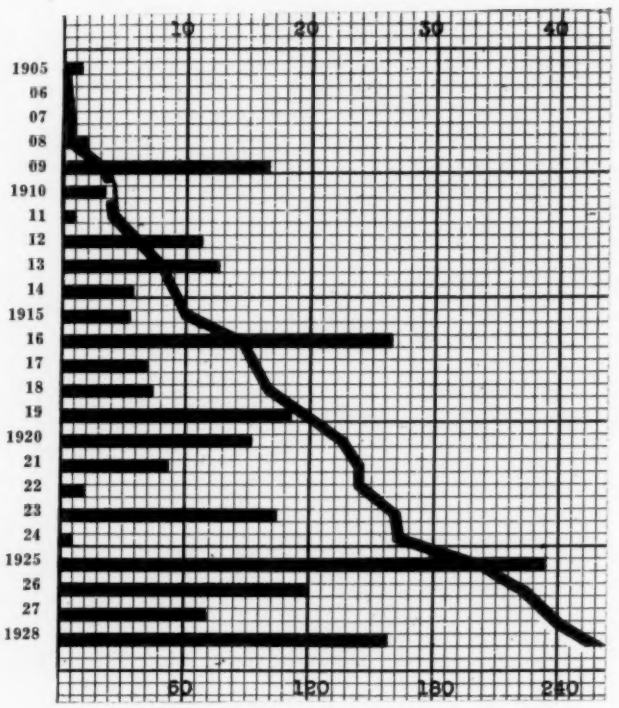


FIG. 11—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Merchant Mills.

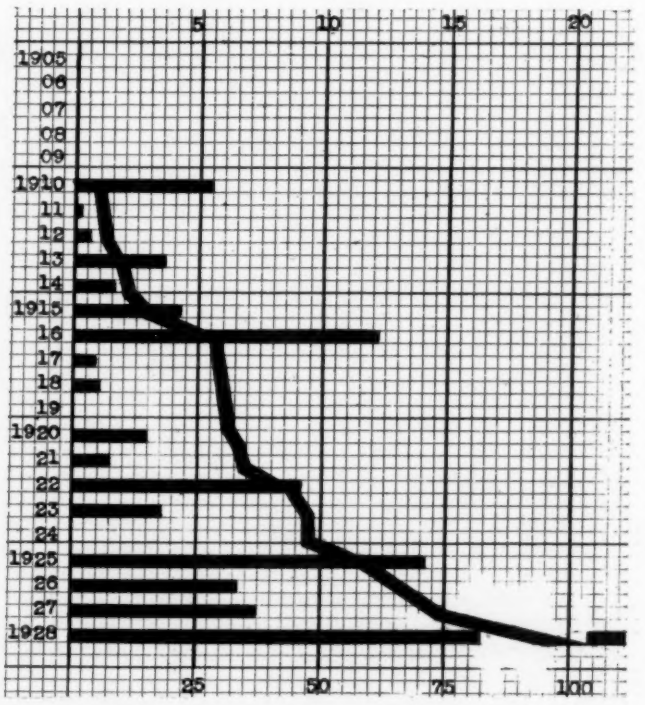


FIG. 12—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Rod Mill.

GENERATORS

Whirling with a rim speed of 273 miles an hour, about twice as fast as the average airplane travels, is the function of the long steel drum of a turbine-generator—70 or 80 tons of spinning steel whose slightest weakness would be disastrous. The general standby of all industry, carbon steel, has in the past been unequal to it.

No development of the steel makers' art has been more notable in the last few decades than the appearance of alloy steels. The magic that could be worked with a few per cent of this or that has led metallurgists on until there seems scarcely any desirable property of steel which may not be hoped for in some alloy. However, these successes farther afield have perhaps distracted attention from the possibilities of the old standby, carbon steel, itself. Careful study now reveals it as showing unexpected response to skillful heat treatment. Carbon steels developed this year for turbine generator rotors are even better than expensive alloy materials.

Nowhere in the world, it is thought, is its like: 60,000 lbs. per sq. in. yield point (not ultimate limit); 25% ductility (though ductility usually does not go with high strength), and an extraordinarily high dynamic stress reactance, ability to withstand fatigue.

Special methods are used in forging these great masses, to get good directional arrangement of grain structure. Reheating eliminates excess directional grain formation. Then follow quenching and tempering in a manner never before attempted. Needless to say, all the large-scale metal treatment follows a long metallographic study with furnace and microscope. It is another laborious forward step in meeting the public's insatiable demand for more electricity.

The generators of the Brooklyn Edison set are the largest ever equipped for self-ventilation. Self-ventilation is desirable because of its simplicity and low maintenance cost but heretofore the mechanical stresses in fans of the necessary size, at the required speed, have been prohibitive. The new fan with doubly curved aluminum blades held between steel rings has, on test, been operated at speeds up to 3300 RPM without sign of distress.

The generator coils are insulated with the newly developed "black bond" and protected from the gradual effects of corona by the Aquadag process.

Special high grade steel is used for the magnetic circuit—the same 4% silicon alloy which was originally developed to meet the exacting magnetic quality requirements of transformer work.

There was a notable increase in the voltage of generators for turbine sets.

The first 16,500 volt generator was placed in operation in the Long Beach Station of the Southern California Edison Company. It is rated 100,000 KVA, 50 cycles, 1500 RPM; and in spite of its exceptional size and weight, the stator which has a frame of welded construction was assembled, wound, tested, and shipped as a complete unit.

The Super Power Company of Illinois at Pekin has one unit installed and a duplicate under construction with generators wound for 22,000 volts, rated 61,765 KVA, 1800 RPM.

The generators for the 208,000 KW triple cross compound set for the State Line Generating Company are also wound for 22,000 volts.

A single generator having a double winding and a total capacity of 160,000 KW is being built for the New York Edison Company. It is the largest and highest rated generator so far constructed.

TRANSFORMERS

The three-phase transformer for the United Electric Light and Power Company of New York is the most powerful self-cooled transformer ever built. The 43,333 KVA single phase units installed this year at Plymouth Meeting, of course, rate more, but 10,000 KVA of their capacity is due to an air blast on the radiators. The same assistance given the other would raise the rating to the neighborhood of 50,000 KVA.

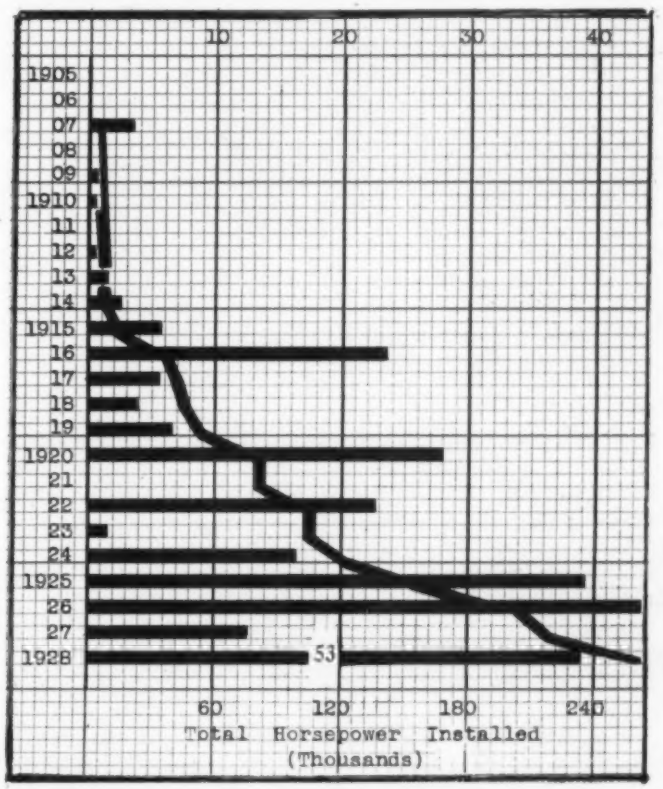


FIG. 13—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Strip Mills.

The efficiency is extraordinarily high—99.54%, perhaps the highest ever reached by any electric machinery.

Two three-phase air-blast transformers, greater in kilovolt-ampere capacity and larger physically than any so far produced, were completed for the Waterside Station of the New York Edison Company, where they will operate in connection with a 40,000 KW induction-synchronous frequency-changer set. Each unit is rated 25 cycles, 18,500 KVA, 11,800/-3300/440 volts.

They are of shell-type design with rectangular coils, a construction used to distribute the cooling air at high velocity correctly throughout the windings and core. Despite their exceptional capacity, these transformers each occupy a floor space of only 6½ by 11 ft.

LOCOMOTIVES

Electric Locomotives

A mill can turn out product only as fast as it is fed with ingots lifted glowing from the soaking pits. A new locomotive at the Aliquippa Works of the Jones and Laughlin Steel Corporation can feed the mill with 75 four-ton ingots hourly, a considerable increase over former methods. The distance between soaking pit and mill, averaging 325 feet, is covered quicker than the fastest subway would make it—48 seconds round trip, with eight seconds standing time. The "train" is the 20-ton locomotive, and a 14-ton ingot car or "buggy" with its red-hot 4-ton load. So short a run is all starting and stopping, the car never reaches full speed. The locomotive has two 150 HP motors with mica and asbestos insulation, cooled by forced ventilation, electro-pneumatic control, and airbrakes—features customary in regular railway practice, but rare in engines of this industrial type, unprecedented in this ingot-carrying service. In case of failure of the engineer, a "dead man's handle" on the controller cuts off power, sets the brakes, sands the track, makes sure that the four-ton mass of red-hot steel will not run wild.

General speeding up of material movement in manufacturing is a very common tendency, but so conspicuous an example, requiring elements of high-speed electric railroading, is unusual.

Gas Electric Locomotives

The faithful dinky steam locomotive, which has fascinated so many small boys, is at last menaced by gasoline and electricity. Trolley locomotives never seriously entered this field. In such service, tracks are often rough and temporary, trolley wires probably undesirable, as for example, serving steam shovels, or inside buildings. But the gas-electric drive, developed for rail cars and buses, is obviously fitted for industrial and contractor's engines.

The 44-ton engine, owned by the Northern Illinois Coal Co., is believed to be the largest gas-electric industrial locomotive actually operating.

It hauls four 65-ton loaded cars of coal at each trip from the strip mine to the tipple. The track is directly on the exposed rock, and there are occasional very steep short grades. Two 140 HP gasoline engines drive the generators—four mining-type motors are axle-mounted in the usual way. Control is by the engine-throttle.

The new engine costs less to keep up, it is less hurt by bad water supply, and the care of a gasoline engine is beginning to be understood by more people than that of a steam engine.

Oil-Electric Locomotives

A total of thirteen oil-electric locomotives were completed or under construction during the year. They include a number for industrial service, such as those for the Donner Steel Company which is using four 60-ton units each equipped with a 300-HP engine, the American Rolling Mills Company's 100-ton unit equipped with two 300-HP engines, and three 74-ton units each equipped with one 300-HP engine.

CRANES

A survey of the crane situation brings out some interesting information. During 1928, 43% of the cranes purchased were completely equipped with anti-friction bearings and 11% partially equipped.

There is also an increasing trend toward worm gear reduction. 12% of all the cranes purchased by the Steel Industry during the year 1928 used worm gear reductions.

One of the crane builders is advocating the use of spring end carriages. It seems logical to believe that a certain portion of the wear and tear on traveling cranes is due to the vibration setup when crane travels on runways. It is true also that traveling cranes are practically the only vehicles today which are not equipped with some spring device to minimize shock.

CONTROL

Time-Current Control

Time Current Control has been under development for several years to meet the requirements of steel mill engineers and to avoid the limitations of existing systems of control. The ideal system of control was considered to be one in which the time of acceleration would be short in order to get maximum production and which would permit light loads to be accelerated more rapidly than heavier loads and at the same time to provide a system of acceleration which would force the motor to start under abnormal local conditions. These requirements have all been met in Time-Current control.

The time current acceleration relay used on the Time Current control has only one moving part, an aluminum sleeve, carrying the contact bar. The application of this control is being watched with interest and if production is to be increased, as it would seem it can be, it will be gladly received by the steel industry.

An ingenious interlocking control system was devised for the operation, at predetermined time intervals, of chutes delivering sand, gravel, and cement to a traveling belt so as to secure automatically an accurate mixture for concrete. This arrangement eliminates the operator as a factor in securing any given mixture required.

The conveyor belt operates at a uniform speed and passes below a series of hoppers, each of which is motor-operated and provided with reversing contactors, selector switches, and definite-time relays. In the equipment already constructed, the chutes from each hopper are lowered in sequence for an interval of four seconds, after which they are raised to the closed position. The limit switches are so arranged that the operating lever is thrown in one direction by the action of the hinged chute when it is lowered and in the other direction when it is raised. When the motor is cut off the line, it also de-energizes the solenoid brake coil so that the motor will be held stationary and will not coast.

AUXILIARY MOTORS

An improved single-phase repulsion-induction motor, in sizes ranging from ¾ to 2 HP at 1800 RPM, is of the constant-speed high-starting-torque type for general application.

One of the most important improvements is the more efficient use of the stator punchings which was accomplished by taking full advantage of the design possibilities of the polar winding of a repulsion motor. The most desirable distribution of stator coils in a repulsion motor is a sinusoidal distribution. This means, therefore, that the number of turns in the various coils of any one pole varies according to the angle from the pole center. Full advantage has been taken of this possibility by designing a four-pole motor using a square punching with graded slot depths, the slots being so arranged that the deep slots are placed at the corners where the maximum core is available and the shallow slots placed in the flat portion of the punching where minimum core is adequate.

Among generally accepted electrical ideas are two: (1) that direct-current dynamos are hardly feasible much above 1500 or 2000 volts per commutator, and (2) that, in general, small machines are harder to build for high voltage than large ones. A startling exception to these rules is the 10,000 volt, 20 KW, DC generator built for the Navy. Six of these are to be used in radio work, to supply plate current for large transmitting tubes at Arlington.

The generator itself is, in general, of normal design. It was not found necessary to adopt any extraordinary means to attain its high voltage. It is bipolar with two commutators in series. There are commutating poles, but no compensating winding. The field frame is of welded steel plate with fabricated feet welded on. The cylindrical frame is carried out to the bearings, so that the end bells are mere discs, and the whole machine has a singularly inconspicuous and non-committal appearance. Ball Bearings are used. The speed is 1750 RPM.

The tests included short-circuiting ten successive times at full voltage—there was substantially no damage, and the machine continued operative.

During the past year the Electro-Dynamic Co. developed and built six high speed motors for use on submarines for the Navy Department. These motors were rated 176 HP, 20 minute, continuous duty, 230 volt, 4800/5200 RPM. The motors are semi-enclosed and directly connected to low pressure blowers and were used for blowing the ballast tanks just as the submarine gets to the surface after the conning tower hatch has been opened. These motors could carry a continuous duty rating of 125 HP.

The complication added when starters are used with motors of smaller sizes has resulted in the design of line-start motors. These can be thrown directly across the line without exceeding the value of current permitted by the NELA.

The elimination of equipment which may cause delay and at best adds to maintenance charges is another step in the right direction.

SPECIAL INGOT CONVEYOR

There is in construction at the present time a special ingot handling conveyor which we believe is something new in the Steel Industry.

A special crane handles four ingots at one time, taking them from the Stripper crane and depositing the four ingots at one end of the conveyor. This continuous conveyor is 500′ center to center of sprocket wheels. These wheels being approximately 10′ in diameter. The conveyor is built up of cast steel ingot cars, coupled together by hardened pins forming a double hinged joint. The cars, themselves, serving as a chain engaging the sprocket teeth, one on either side of the car.

Each car is equipped with four track wheels, two on either side which roll on double track. These wheels being equipped with roller bearings. Each car is equipped with two pots, suspended on four heavy springs for receiving the ingots. There is a total of 258 cars in the conveyor, and 516 pots.

The drive for the conveyor is made up of driving sprockets, spur gears, and worm unit to which is attached at either end, two special variable speed motors through flexible couplings. However, one motor only is used at one time, the other motor being uncoupled and in reserve for emergency in case the active motor should go out of service. Each motor is operated with its individual control.

This conveyor runs in front of the Soaking Pits in a continuous slow movement. The ingots being deposited at the receiving end by the special designed ingot handling crane mentioned above, 4 ingots being deposited at one time.

The charging of the ingots from the conveyor to the Soaking Pits is done by three cranes, each crane serving a certain section of the Soaking Pit building. All of these motions are performed whle the conveyor is in motion.

One of the outstanding advantages of handling ingots in this manner is minimum loss of heat between the time of stripping the ingots and depositing same in the Pits.

The height of the pots in the conveyor is approximately the same height as the top of the Pits-which allows a minimum vertical lift for the pit cranes.

PORCELAIN INSULATORS

There have been no vital changes in electrical porcelain insulators other than certain improvements in the ceramic material and factory processes. On the other hand, a number of special problems have received a great deal of attention. Among these problems may be mentioned the development of corona proof pin type units, insulators for foggy or dirty atmosphere, and fused grading shields for protecting important lines which are carrying heavy synchronous loads.

The corona proof insulators consist of ordinary pin type insulators with a metallic coating over the tie wire groove and a metal thread in the pin hole. Concentrated electrostatic stress on the air around the tie wire and base of the pin is thus reduced to a minimum and the corona point of the insulators materially increased. It is hoped that such assemblies will be an aide towards the reduction of radio interference emanating from high voltage lines.

In designing insulators for foggy and dirty territory, it is important that they should have a long enough leakage path to prevent excessive creepage. Of no less importance is the necessity of having the surfaces of fog type designs easily accessible for the purpose of cleaning. Experience has shown that under bad conditions of dirt all insulators must be washed from time to time and no design should neglect to take account of this fact.

The fused grading shield has been installed on lines equipped with heavy synchronous loads. These devices are similar to the well known grading shield which consists essentially of a metal ring placed around the lower end of a suspension insulator string. At the top of the string another ring or set of arcing horns is provided. The function of this equipment is to prevent damage of the insulator units due to flash-over. The fused grading shield fulfills still another function of paramount importance. Instead of a ring or horns at the top of the string, fuses are placed in such a position that the first discharge over the string strikes between the fuse and lower ring. The fuse blows in about one cycle, and prevents the establishment of a power arc. The circuit breakers, therefore, do not operate and the synchronous load on the line is not dropped. Transmission lines equipped with insulators and fused grading shields have now been in successful operation for some time and are no longer in the experimental stage.

LUBRICATION

A typical lubrication installation is that on a three stand, 10" Hot Strip Mill in an Ohio plant which includes the 450 lb. grease capacity lubricator operated by a 1 HP compressor set with automatic cut-out pressure switch. A working pressure range between 175-225 lbs. per square inch is maintained in the lines.

The special roll neck lubricant is piped up on each stand and branch lines are connected to each distributor pipe located over the necks. There is a pressure control valve opposite each neck.

By maintaining a constant supply of suitable lubricant, bearing life has been doubled and a saving of 15% in power consumption has been effected.

During the past year considerable development has been done in order to provide greases which will give satisfactory operation under very high temperatures. Considerable progress has been made and consequent savings effected.

MISCELLANEOUS DEVELOPMENTS

Instrument Transformers

Accurate metering of large blocks of power is of increasing importance to the electrical industry. A small error in the metering equipment at the tie-in point of a present day system of inter-connection can easily represent thousands of dollars' loss annually.

Silicon steel, widely used for instrument transformers, has a serious rival after twenty years of undisputed reign. Hipernik, an iron-nickel alloy of vastly superior characteristics, made its debut in the power field this year; instrument transformers, has a serious rival after twenty years of undisputed reign. Hipernik, an iron-nickel alloy of vastly superior characteristics, made its debut in the power field this year; instrument transformers, smaller and more accurate than any hitherto known have been produced. The phase angle error is about one-third that of a silicon steel core of the same weight and Hipernik gives an unusually flat ratio curve over the operating range.

Carboloy

A new tool material, composed of tungsten carbide and cobalt, was developed. The material is extremely hard and the cobalt gives it the strength necessary for cutting tools. This hard metal composition will be marketed under the trade name "Carboloy."

The material is particularly valuable in the cutting of low-tensile materials which are abrasive to the present type of tool, and in this class of work Carboloy tools have been found to be from 25 to 75 times as durable as high speed steel tools. It can also machine harder and denser grades of steel than can be handled economically by high-speed steel, machine rods of glass or porcelain, or drill holes in concrete and rock where it was formerly necessary to use either an expensive diamond drill or a star hammer.

The addition of cobalt to the tungsten carbide increases its strength to more than half that of high speed steel. Tungsten carbide without cobalt has a strength of less than 50,000 lbs. per sq. in., carboloy up to 275,000 lbs., and quenched and tempered high speed steel 425,000 lbs.

The material retains its strength and hardness at high temperatures to a remarkable degree and tools made of it have been observed cutting nickel steel when the point of the tool was at a bright red heat, without showing any ill effects. It has no temper to be drawn by the heat generated.

Copper Brazing Furnace

Furnaces of different types for copper-brazing steel parts together have been in the course of development for several years and are now being used in large-scale operations. By this process a number of separate pieces can be joined into an assembly at one operation, the resulting joints being liquid or gas tight and exceedingly strong. A number of such furnaces were installed during the year. An atmosphere containing hydrogen is maintained in the furnace, which excludes air and assists the process in other ways. This process can be adapted to many lines of manufacture, and the furnaces are also suitable for bright-annealing certain metals.

Furnace Temperature Control

A thyratron was adapted to furnace temperature control. The temperature of the furnace is measured by a thermocouple or resistance thermometer connected to the grid circuit of the thyratron in such a way that when the temperature is below the desired point the thyratron carries current sufficient to operate a contactor requiring two or three amperes. In the past very delicate mechanical devices have been used as relays to enable the heavy furnace currents to be controlled by the extremely minute currents from the thermometers. The thyratron supplies the most sensitive relay means yet found for amplifying these feeble impulses to control the large amounts of power used for furnace heating.

The information contained in this report is compiled from data furnished by the members of the Electrical Developments Committee. The only part which the author has played has been to arrange it in suitable form for presentation.

The Incorporation of Safety in Electric Station Design

By V. R. BACON†

Safety for life, property and the continuity of service should be a quality inherent in all electrical structures and, being a fundamental characteristic, can be engendered only as an element of design.

Complete safety is unattainable, but this generality can never be a justification for laxity in the consideration of the specific details. The degree to which safety should be incorporated must necessarily be tempered by the nature of the equipment, the importance of the installation, various local conditions, and the funds available.

Safety is clearly a general subject which cannot be discussed comparatively or quantitively without

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direct association with a specific problem. It is, therefore, the intention of this paper to consider the subject in a purely general manner without attempting to compare the various safety expedients or to specify their degree of application. Such decisions must be left to the judgment of the designers responsible for each individual project.

Most of the points discussed are those which have come to light through past experience in every day design and operation and no attempt is being made to treat the subject exhaustively. Many of these points will seem superficial and commonplace but in spite of their appearance they are being continually overlooked.

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General Co-ordination

Too much emphasis cannot be placed on the necessity of thorough correlation, for the promotion of general safety, between the building details and the allocation of electrical equipment.

At the outset of the preliminary design, the matter of fire and explosion hazard should receive detailed consideration. Such reflections usually indicate that enclosures containing large oil switches, transformers, storage batteries, etc., should be kept to the outside of the building and away from essential equipment. An arrangement of this kind is ideal but is rarely ever accomplished due to justifiable economic reasons. The hopelessness of the ideal, however, should be no bar to the effort toward partial attainment.

The possibilities of disastrous fires and losses can often be minimized by the installation of oil barriers on the floors of enclosures housing oil filled equipment. Such barriers, if possible, should be made an integral part of the floor and so designed as to divert oil, accidently released, to proper drains. The barrier system is, of course, of little benefit unless the drainage system is of sufficient capacity and so designed as to insure the discharge of all free oil in a minimum time.

Battery rooms always constitute a potential explosion hazard and much of the danger can be eliminated by locating and arranging the battery room to take advantage of natural ventilation. When natural circulation is employed, care must be exerted to insure that the battery will not be operated at disadvantageous temperatures. In the absence of natural ventilation, it is advisable to consider the possibilities of forced circulation of some kind. This usually involves the installation of more or less duct work which should be constructed of vitreous or acid resisting materials to avoid rapid deterioration and the possible failure of the circulating system.

Battery room explosions can further be minimized by the use of gas proof lighting fixtures and switches. Such fixtures should preferably be of the flush type since they are more easily protected from the action of the acid fumes.

Ample exits from potential danger zones are of paramount importance. Preliminary layouts should be carefully studied and arranged so that enclosures, containing equipment, in any way addicted to fires or explosions, are provided with liberal exits, easily reached from all points within. Where such exits may be closed, the doors or gates and their casings should be of such material and assembly that possible failure to swing freely or operate in both directions and under all conditions is reduced to a minimum. Doors which might, at any time, be used as emergency exits should be equipped with panic locks and should swing into safety areas.

Door and aisle ways should be given careful at-

tention. As a rule, these ways are cut to the minimum necessary to pass the largest piece of equipment expected to move through them. Such scant clearances may be perfectly satisfactory for routine conditions but may become wholly inadequate and even dangerous for both men and materials in the haste of emergency repairs. It is, therefore, advisable, when possible, to base the dimensions of door and aisle ways on emergency conditions rather than on those of leisurely construction operations and maintenance.

The choice of floor finish often becomes a vital factor in ultimate safety and serious falls can be averted by the proper correlation between the floor finish and equipment. Floors in the vicinity of oil filled equipment often and unavoidably become oily during maintenance and emergency operations. If smooth finished, they may become very slippery, particularly when rubber heels are in use. Such floors should preferably be rough finished. Rough finishes, of course, make good housekeeping difficult and the finish chosen should consider that point.

Another condition of hazardous footing is often created by the freezing of spray blown from flow sight openings on outdoor, water cooled transformers. This condition is usually very difficult to remedy but can be alleviated to some degree by the shielding of the sight openings or by special floors or finishes.

The subject of general lightning is a matter which can well be taken seriously and given detailed attention throughout the design of any project. It is not sufficient to have only enough light for satisfactory normal operation, but adequate light should be available where and when wanted for all emergencies. The equipment layout should be studied as a whole and in detail in an endeavor to evaluate the importance of the various items, the danger points created by their combinations and the likelihood of failure inherent in the particular pieces. The lighting system should then be laid out accordingly.

As a general rule, it is advisable to consider the provision of an emergency lighting circuit, which can be fed from a separate and dependable source. This circuit should include all lighting and plug outlets likely to be necessary in case of a general lighting failure and should be arranged for normal supply from the station lighting busses and automatic transfer to the emergency source upon loss of bus potential.

The station battery usually possesses all of the requisites essential for the emergency lighting source and is generally employed for that purpose. Under such conditions, only absolutely essential lights and outlets should be included in the emergency circuit in order to prevent excessive drains on the storage battery at times when its availability may be of vital importance. Obviously, the battery should not be used for the emergency lighting if any other satisfactory source is available.

Every effort should be made to provide adequate natural lighting, coordinated with the characteristics and importance of the individual pieces of equipment. In laying out the window locations, particular care should be given to the choice of sash with reference to the type of apparatus in the immediate vicinity. Unless this point is continually watched, movable sash windows may be installed over or near high voltage equipment which may be short circuited by rain blown in through the window opening. The location of window operating rigging and linkage also requires detailed attention in order to insure adequate maintenance clearances between the various parts of the operating mechanism and high voltage conductors or live surfaces. It is not infrequent that sash operator hand wheels are so located with reference to live equipment that they cannot be hurriedly operated with safety. These dangers can almost always be eliminated by careful checking in the preliminary stages of the design.

The station piping system should always be regarded with some suspicion from the viewpoint of the electrical design and, in general, it is always best to keep electrical equipment out from under piping of all kinds. This is seldom possible and other expedients must be resorted to. Pipes carrying cold fluids are apt to sweat on hot humid days and there is always a possibility of moisture dripping onto live equipment and resulting in short circuits or other difficulties. This danger can usually be overcome by covering the offending pipes with an effective heat insulation. Steam and hot water pipes are potential hazards since there is a tendency for them to leak at one or more points. Where electrical equipment cannot be kept from under such pipes, the simplest remedy is the installation of gutters under the pipes or shed roofs over the equipment. The latter expedient should be applied with considerable care to avoid the danger of raising the normal operating temperature of the equipment to unsafe values due to loss of free air circulation.

In cases where it is necessary to install bare conductors under insulated piping, it is advisable to be reasonably sure that the banding used to secure the lagging is not of a kind which is likely to break and fall in such a way as to result in short circuits or grounds.

The cost of adequate communication and signal systems can generally be justified as safety insurance. These systems should be designed with great care in order that their range of utility may cover all reasonably expected emergencies and that their general serviceability may not be impaired by abnormal conditions under which they are expected to function. This applies not only to telephones but to miscellaneous signal systems as well.

Comprehensive telephone and signal installations have their value in the provision of quick and quite certain means of transmitting orders to all parts of a plant from any point in times of emergency and may, also, provide a means of communication between the outside and men unexpectedly trapped in unsafe places by accident.

Boiler and turbine room load indicators are frequently of great service in keeping operators and attendants informed of load conditions during emergencies, thereby permitting them to act independently in the absence or failure of the central authority. Turbine room synchroscopes have proved their worth in several instances when heavily loaded stations have been accidently dropped from a system and the remaining generating capacity has been insufficient to maintain the frequency within the range of the governor controls of the delinquent station. In emergencies of this kind, the turbine room synchroscopes greatly aided in getting the station back into service on the throttle.

The number and location of toilet and drinking water facilities is a matter quite often given too little consideration and, not infrequently, a false economy is affected by reducing such facilities to a minimum, particularly in the smaller plants. The number and location of these facilities should be so related to the location and importance of the various posts of duty that operators and attendants may be justifiably absent from their posts a minimum length of time.

Careful co-ordination between the building details and the inherent characteristics of the various pieces of equipment will often result in decided operating advantages. This is particularly true with reference to self cooled devices. Frequently the safe load capacity of transformers, regulators and similar equipment can be materially increased by minor changes in location or in building details which greatly improve their natural cooling. Conversely, the normal carrying capacity of such equipment is frequently seriously reduced by failure to take advantage of available natural ventilation.

The same idea applies equally well to conductor insulations. The matter of idle temperature should be given detailed consideration throughout the progress of the conduit and cable layout in order that the conductor losses, superimposed on abnormal idle temperatures, will not deteriorate, or contribute to overstresses on, the insulating material. This point should receive particular attention in the vicinity of boilers, heaters, etc., and in floors immediately above devices which liberate large amounts of heat. Where high idle temperatures are unavoidable, the difficulty can usually be remedied by the proper choice of insulation.

Safe ratings for the individual components of the electrical system, in themselves, are not sufficient and, for greatest safety, the system must be considered as a whole and the ratings and characteristics of its parts co-ordinated, one to the other.

The difference between the standard test voltages prescribed for the same type of equipment used in and out of doors and the difference between standard test voltages for different types of equipment often leads to heterogeneous combinations of insulation values on conductively connected networks. The situation is made still more acute by the frequent necessity of using circuit breakers of higher than normal voltage rating in order to secure satisfactory rupturing capacity. This results in unequal insulation stresses throughout the network and frequently the most highly stressed insulation is found to be in a decidedly disadvantageous position. This difficulty can seldom be wholly rectified but it can usually be considerably alleviated by a careful survey and balancing of insulation values. Occasionally the most severe stress can be assigned to equipment which can be readily repaired or for which there are adequate spares available. Thus, the disastrous results of the almost inevitable flashovers may be somewhat moderated by careful planning.

During the progress of the general electrical layout, much can be gained in ultimate safety by a detailed consideration of possible concentrations of power which may be fed into a short circuit. This is a point seldom overlooked in the larger projects and disastrous short circuits are, to a large degree, forestalled by the careful sectionalizing of the electrical structure through the use of reactors. This matter is not always given the attention it deserves in the case of the smaller projects and, particularly, in the instance of industrial sub-stations connected to large power systems.

Rotating Equipment

Short circuits and fire are probably the greatest and most common hazards to which rotating equipment is subjected.

The possibility and danger of short circuits cannot be entirely removed but the damage resulting from internal insulation failures can be appreciably reduced by the application of suitable differential relaying.

The fire hazard can likewise be materially alleviated by the installation of some form of built in fire extinguishers in cases where the importance of the equipment justifies the expenditure. There are several types of built in carbon dioxide extinguishers now available which are apparently giving satisfactory protection. These are rather expensive and satisfactory substitutes have been sought through other agencies. There are, at present, several installations where water or live steam are used as the extinguishing fluids. In these instances, the generator housings are permanently piped and arrangements made for drenching the windings or displacing most of the air within the housing on a moment's notice. At first thought, an expedient of this kind would seem to possess many disadvantages. Nevertheless, the operators making use of such systems seem to be fully satisfied.

The different schemes of high speed excitation recently introduced may be considered as safety devices in that they are designed to return a system to normal in the shortest possible time after an electrical disturbance. High speed excitation, however, should be considered with care, since its normal functioning at times of short circuits tends to produce currents of abnormal magnitudes and, unless means are provided to limit the value of the short circuit currents, the application may be entirely detrimental.

Due to the ever increasing demands for larger generating units and their attendant economies, a point seems to have been reached where the large concentration of energy on a single shaft has become a hazard of no small importance. This condition has led to the consideration of double winding generators. While no such machines are in operation at this time, the present interest in them seems to be a step in the right direction. Their theoretical merit, from the viewpoint of safety, rests in the indications that the double winding will permit a simpler and more effective means of bus sectionalization and that one winding may be serviceable even though the second may be damaged.

The difficulties encountered in feeding long, high voltage transmission lines justify considerable thought in the selection of generators and their auxiliary equipment. Where long lines are involved it is highly advisable to secure the close co-operation of the generator manufacture in working out the generator application. If this is not done, there is a possibility that the loss of the far end load will result in voltage compounding in the generator which

may not only overstress the generator insulation but all other insulation in the conductive vicinity of the machine. Dangers from over compounding can generally be eliminated by proper relaying, correct application of voltage regulators and the provision of adequate rheostats.

Temperature indicators of the exploring coil or thermo couple type always constitute a potential hazard since they provide a conductive circuit between equipments which normally operate at respectively high and low potentials. The dangers from these instruments can be largely overcome by the proper installation of film disc or similar cut outs or the symmetrical and permanent grounding of all temperature sensing elements. When grounding cut-outs are used, care should be exerted to see that they are installed in a thoroughly dry location and that ample provision is made for their inspection and replacement. The expedient of permanent grounding is probably the more reliable means of protection. It has the disadvantage, however, that it usually necessitates the use of a separate battery for the indicator system.

The design of ducts for air circulation through rotating equipment warrants consideration with reference to the method of fabrication. Since these ducts are generally made up of flat plates, there is always a tendency for the plates to vibrate under the action of the rapidly moving air and, unless they are permanently and tightly fastened together, there is a possibility of considerable wear in the joints. The products of such wear, on the injection side of the machine, may be picked up by the air current and deposited in the windings. This deposit is, as a general rule, both magnetic and conducting and may, sooner or later, cause trouble. Therefore, all reasonable effort should be made to prevent joint wear in metallic duct lines supplying air, at high velocities, to rotating or other air cooled electrical equipment.

Where structural or other conditions necessitate that ducts be so constructed that low points or pockets are unavoidable between the machine and the intake opening, there is a possibility that considerable water may be trapped in the ducts while not in use. Under such conditions, the ducts should be thoroughly water proofed or effective baffles provided between the machine and the nearest low point. Unless this precaution is observed, there is danger of thoroughly wetting the windings on starting up the machine after a period of idleness.

Occasionally an instance will occur where space limitations will indicate that neutral current transformers should be installed adjacent to the terminals of a turbo generator and in the air passage. Such installation should be avoided if possible. However, if there is no other alternative, the transformers should be provided with a substantial fireproof housing to prevent the possibility of transformer trouble being communicated to the generator terminals and winding. This housing, of course, should be designed with a view to the prevention of deterioration resulting from vibration induced by the air currents.

Uncovered couplings on rotating equipment are rather a rarity at the present time. Nevertheless, some are still found. As a rule, their existence is justified by the fact that they are of the smooth type having no projections to catch in clothing or engage with passing objects. This argument is perfectly sound as far as it goes but the uncovered couplings remain a hazard. Their condition at the time of installation is neither a guarantee that they will not become rough through usage, rust or general abuse nor an assurance that they may not become coated with a sticky substance or be brought into contact with threadbare clothing or clothing covered with an adhesive material. The same reasoning applies equally well to any exposed shafting likely to come in contact with personal clothing.

Bus Structures

The bus structure is probably the most vital and vulnerable part of the entire electrical fabric. It exercises enforcement over a part or all of the system and is often conductively or inductively connected with large blocks of generating capacity. It, therefore, becomes an integral part of the whole system, in the case of interconnections, and not merely an element of the plant with which it is associated. Hence, the design of the bus structure demands the most minute consideration.

The importance of the bus structure has been recognized by the manufacturers and they have made great advances toward the assurance of safety. There are a number of different styles of factory built and fully enclosed bus and switch structures now available. These fall into two general classes, namely, oil or compound insulated and air insulated. All, of course, employ additional solid or semi-solid insulation for the purely mechanical purpose of insuring proper conductor spacings. Equipment of this nature goes by various descriptive names such as "truck type," "oil insulated" and "iron clad." In all instances, the manufacturers have made an earnest effort to anticipate probable troubles and danger points and have, in general, made noteworthy progress toward ultimate safety in bus structures. All of these types of metal enclosed structures merit consideration in almost any application.

Thus far, the factory fabricated bus structure has not succeeded in supplanting the field built structures. These are usually constructed from concrete, brick or patented, heat resisting compositions having electrical resistance considerably higher than either of the former.

Field fabricated structures are of two general arrangements commonly known as the isolated phase and group phase types.

The isolated phase arrangement attempts to keep the physical position of all phases, of the same instantaneous polarity, parallel and adjacent and isolated from each other but in the same general enclosure. In contrast to this, the grouped phase arrangement places the physical position of the individual phases in parallel and repeating sequence, each phase isolated from the other and each complete sequence isolated from the adjacent sequence.

The isolated phase scheme reduces the maximum mechanical forces on the busses and insulators and practically eliminates the dangers of phase to phase shorts. It does, however, tend to complicate switch and operating mechanisms and frequently introduces serious difficulties in this respect.

The group phase scheme permits the maximum mechanical forces, for the same spacings, on bus bars and insulators and increases the chances for phase to phase shorts. Nevertheless, these hazards

are frequently offset by the simplicity afforded in the switch linkages and mechanical operating mechanisms.

There are several points, sometimes overlooked, which should be reviewed with reference to the design of field fabricated structures.

Almost invariably, there is an urge to allot too little space to the bus structure. This results in a tendency to crowd which produces insufficient, or at least questionable, clearances from the viewpoint of safety. The bus structure is important enough to demand recognition and every effort should be made to secure ample space not only for safe electrical clearances but also, for safe emergency and maintenance operations.

When patented, high resistance structure compositions are used, there may be some tendency to overcapitalize their insulating qualities. For this reason, an attempt should always be made to anticipate and guard against probable future circumstances which might reduce the resistances below the published values.

The design of all field fabricated structures should be such that the various phases can be symmetrically arranged and can occupy the same relative positions in all parts of the structure. This will greatly facilitate proper marking and will do much to guard against operating errors.

The structures should be laid out so as to make isolation as complete as reasonably possible. Care should be exercised to avoid chimney effects which might propagate trouble from one point to another and the subject of baffling against arc communication, in general, should receive considerable attention. It is to be remembered, however, that barriers of any kind tend to increase the idle temperature of busses and equipment. The extent of baffling must, therefore, be carefully balanced against safe carrying capacities. In addition to this, baffling may introduce the necessity of additional insulators and bushings. When it is considered that every insulator is a potential hazard, it is immediately evident that the quantity of baffling must be tempered by the amount of additional insulator hazard introduced.

The rapid growth in physical size and rupturing capacities of oil circuit breakers has introduced new difficulties in bus structure design. The high speed operation accompanied by the almost instantaneous decelleration of heavy parts now common in modern breakers demands a most careful consideration of the switch supporting and fastening details. It is, therefore, essential that the breaker mounting as well as the bus structure in the immediate vicinity of the switch be given proper attention to forestall the possibility of the breaker moving out of place when operating under heavy shorts and the disintegration of the structure by the hammer action of the switch in normal operation.

Since practically all concrete, brick or composition bus structures are bonded or bound with steel either internally or externally, there is always a chance for short-circuited magnetic loops which may act as single turn transformers in the presence of residual fields. These loops, under proper conditions, may carry a considerable amount of current which may result in serious local heating and an ultimate weakening of the structure. As a general rule, little difficulty is experienced from this source. Nevertheless, the presence of closed magnetic loops is a potential hazard and their formation by structure binding and re-inforcing is to be avoided.

For economic reasons it is always desirable to keep all cell walls as thin as possible. It frequently happens, however, that the thin walls require cell doors whose total area is but little greater than that of the opening they are intended to cover. Thus, there is a chance that unhinged doors may be projected into the cell during the operation of replacement. The results of such an occurrence cannot be foretold, but its possibility certainly justifies the installation of suitable stops to prevent any likelihood of a door passing into a cell. This is particularly pertinent in the case of metal framed doors and their use should be carefully considered unless the design is such that the doors can be permanently hinged and stopped.

Door material as well as locks and hangings should be thoughtfully selected to guard against any likelihood of doors refusing to open when properly released. Such care may save much valuable time in an emergency and many times repay the effort.

The general trend toward larger stations and greater concentrations of power has brought about an increasing extension in the length and size of bus structures. This change has been so gradual that the necessity of providing for expansion and contraction in the longer buses has sometimes been lost sight of and serious, if not disastrous, strains have been superimposed upon both the buses and their supports. This danger can easily be eliminated by proper application of slip clamps on the bus supports or the installation of any of several good expansion joints now available.

Wherever buses may be subjected to heavy inputs of power in the event of short circuits, the mechanical strength of the bus, the bus supports and their supporting structure demands a thorough investigation. In the absence of such consideration, short circuits remote from the bus structure may initiate serious failures within the structure itself.

In course of the investigation of the mechanical strengths just mentioned, it is well to remember that every bus support is a potential flashover hazard. This observation immediately indicates that a considered co-ordination of span, bus strength and support strength will produce a layout requiring a minimum number of supports and, therefore, offering a minimum possibility of flashover.

Tubular buses are subject to all of the considerations applicable to flat buses and, in addition, several others.

Where tubular buses are used out of doors or in places where they are likely to be subjected to freezing weather, provision should always be made to prevent the entrance of moisture which might be trapped and frozen, thus bursting the tubing.

Tubular buses have the same beam strength in all directions normal to their length. This quality has a tendency to promote the approval of greater sags than would be expected in the usual flat bus material. There are usually no serious objections to such sags providing, of course, that the appearance of the work is not impaired and the safe mechanical strengths of the material are not exceeded. Excessive sags, however, should generally be avoided in cold climates, otherwise formations of ice may

occur at the lowest point of the sag and seriously overstress the material.

The design of tubular bus structures invariably involves the selection of various types of conducting fittings and connectors. Many of the fittings now offered are arranged for attachment to the tubing by means of only a soldered male and female joint. This type of joint is customary for flexible conductor work and the familiarity with its use sometimes results in a more or less dangerous oversight. Tubular conductors, as used in bus structures, are semi rigid in nature and are apt to vibrate considerably under the action of the wind. These vibrations are generally carried to the points of support with greater severity than is the case with the more flexible conductors. The effects of these transmitted vibrations, superimposed on large dead loads, often result in the parting of the soldered joint between the tube and the fitting. Difficulties of this nature are more numerous in the case of long drops of small diameter with insufficient intermediate supports. This trouble can easily be overcome by the selection of proper fittings or the provision of adequate stiffness. This does not mean that the slip joint fitting is to be avoided or is deficient for the purpose for which it is intended. It does mean, however, that it must be used with discretion where long unsupported spans are involved.

The design of ultra voltage switching stations is not radically different from that for the lower pressures, but it involves several points not usually associated with the commoner commercial voltages.

At the higher potentials, the air strains are proportionally greater and slender conductors, as well as sharp points, merit detailed consideration to guard against incipient, if not actual, breakdown. Such eventualities can generally be forestalled by resorting to the liberal use of rounded surfaces of ample area.

The higher voltages, along with the increased insulation values, tend to accentuate the difficulties resulting from capacity induction and the retention of residual charges. It is, therefore, wise to provide adequate means for sectionalizing any high voltage bus structure and to install permanently available arrangements for draining each section.

Disconnecting Switches

The ordinary disconnecting switch is a simple, rugged looking piece of equipment and its general appearance sometimes detracts from its true importance. As a result, too little attention is often given to its selection and choice of application. A disconnecting switch is subjected to all of the shocks and strains which may arise in the circuit in which it is connected, and should be selected with as great care as that allotted to any other piece of equipment.

There is a tendency for disconnecting switches to blow open on heavy shorts due to the magnetic forces set up around the blade and the hinge and clip fittings. For this reason, the short circuit characteristics of the circuit should be carefully considered and disconnecting switches provided with simple but effective locks whenever there is the slightest likelihood of their opening under the action of magnetic forces.

While disconnecting switches are seldom assigned to current interrupting duty, there is always a possibility that they may be opened, through error or in unusual circumstances, under load. In anticipation of such eventualities, it is essential that effective barriers or adequate inter-phase spacing be provided in the mounting arrangement, otherwise serious short circuits may result.

Outdoor disconnects are frequently depended upon to interrupt the exciting current of unloaded lines. If such switches are properly selected, difficulty in breaking the current is seldom encountered but it often happens that the rupture arc will stretch out in unexpected directions and to unexpected lengths. Hence, it is very important that the nature of the line exciting current be carefully investigated and the switches given sufficient clearance in all directions.

The practice of gang operating outdoor disconnects has been in effect for some time and it is now becoming common to gang indoor switches to operate from a common lever or hand wheel. Unless effective interlocks are provided to prevent the opening of loaded single pole switches through error, gang operation reduces the chance for mistake in the ratio of three to one for three phase circuits. The advisability of the choice of gang operated switches is, therefore, well worth considering.

Practically all gang operated switches now in service use wrought iron pipe for operating shafts and push and pull rods. The pipe has worked out very satisfactorily for this purpose but is sometimes put out of service by cold weather, particularly when used out of doors. Many of the difficulties of this nature can be eliminated by a careful study of the switch linkage and the provision for the effective drainage of all operating pipes or their adequate closure against the entrance of moisture which may be trapped and frozen.

Since disconnecting switches are, as a rule, infreqently operated, their location and provisions for operation are very often given little thought. Practically every switch in a system may, at some time or other, have to be operated under emergency conditions and may be required to break load current as a last resort if not through error. Disconnecting switches should be mounted at such a height and in such a position as to afford the operator the maximum degree of personal safety and to insure the greatest ease of expeditious operation. Conditions often dictate that stick operated switches be mounted at such inconvenient heights as to make the hooking and operation of the switch dangerously slow and uncertain. This condition can frequently be alleviated by the installation of stick rests or guides which can be supplied at little extra cost and effort.

Any design involving the use of stick operated switches should specifically provide for an adequate number of sticks and their dry and convenient storage in the immediate vicinity of the switches. Where sticks are used for high voltage switches, it is also, highly desirable to provide places for the quick and effective attachment of the rain shed ground conductors. These two points are most easily overlooked in connection with outdoor switching structures and their oversight may, sooner or later, lead to costly delays, if not serious accidents.

The choice of disconnecting switches for the higher potentials warrants detailed consideration with reference to the clear break opening. With the advent of the higher voltages, the construction of dis-

connecting switches has been complicated by the necessity of providing larger gap openings. These complications have usually taken the form of the addition of one or more insulator stacks in the gap space between the outside or connection stacks. From all indications, the insertion of the intermediate stacks materially changes the strain distribution in the air gap and the relative breakdown of the total gap is somewhat lowered by their presence. This possibility is important and its examination in the selection of high voltage switches will not be wasted time.

Oil Circuit Breakers

Oil circuit breakers have two primary functions, namely, the closing and opening of circuits under normal conditions and the interruption of circuits under abnormal conditions. If a breaker fails to perform satisfactorily in the latter case, it is not only deficient in its purpose but may constitute a serious fire and explosion hazard. Thus, it is essential that breaker applications be given the utmost attention. This not only applies in the case of new installations but also in instances where additional generating capacity or additional feeds are connected to small bus and switch structures already in operation. Under such conditions, it is quite possible to add sufficient capacity or to reduce the net reactance between the source and the bus to a point where the rupturing capacity of the existing switches may be considerably exceeded. This is an eventuality frequently overlooked, especially in the case of the small industrial substations.

Modern circuit breakers are now developed to the point where a satisfactory type is generally available for every application and proper carrying and rupturing capacities can usually be insured by reasonable care in selection. These capacities should always be well on the safe side due to the uncertainties inherent in the calculation of maximum short circuit currents.

Practically all of the larger oil circuit breakers now obtainable are of the tank per break type. This construction does much toward reducing the possibility of trouble on one phase being communicated to another and also tends to limit the amount of oil involved in a case of trouble. In certain designs of this type of breaker, the purpose is defeated to some extent by possible flame and gas communication between tanks through the operating rod housings. While the dangers inherent in such construction are problematical, they are, nevertheless, worthy of consideration and can probably be eliminated to a large degree by slight additions or changes in design.

The older and smaller types of breakers used a more or less open construction which made the switch position obvious by external observation. Modern breakers, and especially the larger sizes, are going to an enclosed type of construction which makes the determination of the contact position practically impossible without the use of a semaphore or indicator. Since it may be of importance to ascertain the operating position of a switch from its external appearance, it is essential that the indicating mechanism be rugged and dependable and be plainly visible from the maximum number of observation points in the vicinity of the breaker.

The present tendency of making some oil circuit breakers trip free in all respects except with respect to the emergency operating handle seems to be a very dangerous practice. It acts to impress the operator with the idea that the switch is trip free in all respects and may cause him to, unknowingly, assume unnecessary personal risks. It would, therefore, seem advisable to be absolutely certain that a switch which is trip free in any respect is certainly trip free on the emergency operating handle.

Many of the modern solenoid and motor operated oil circuit breakers do not take their operating current through the switch board control device but draw it from an operating bus in the vicinity of the breaker. This means that an auxiliary relay is usually interposed between the control device and the motor or solenoid. Since the purpose of this relay is the elimination of the necessity of transmitting large draughts of operating current over appreciable distances, the relays generally function on relatively small currents. This means that a ground on one side of the control circuit may possibly supply sufficient current through ground detecting devices to actuate the auxiliary relay and operate the breaker. The likelihood of such accidental switch operation can generally be overcome by ascertaining the minimum current necessary to actuate the auxiliary relay and providing a ground detecting device of sufficient resistance to limit the fault current to a value below that necessary to operate the relay.

Most of the present breakers carry their various control relays on a small panel which is generally mounted somewhere in the immediate vicinity of the switch. Since accidental mechanical operation of the auxiliary relays will generally initiate breaker operation, care should be exterted to make sure that the relays are protected against un-anticipated mechanical closures. It is, also, advisable to provide means for interrupting all control and operating circuits at the relay panel or breaker operating mechanism. This will do much toward the prevention of unintentional breaker operations and possible short circuits on control and operating circuits during tests and maintenance work.

Practically all of the larger breakers available today are provided with vents to relieve internal gas pressures when the switch is operating under high interrupting duty. As a rule, the manufacturers provide an oil and gas baffle in the vents between the breaker tank and the end of the vent pipe and, occasionally, arrange for connecting several vents into a common manifold. Quite frequently too little attention is given to the design when several vents are connected in parallel, thus necessitating a manifold of considerable length. This is a matter which warrants consideration since an improperly proportioned manifold may mean excessive back pressures on the breaker tanks.

Some of the smaller breakers are provided with vent pipes but no baffles and the existence of the vent sometimes suggests the advisability of manifolding. In the absence of effective baffling between the breaker and the manifold, such an arrangement may provide a means of flame communication between phases or breakers and should be used only after careful consideration.

The present day practice of welding practically all breaker tanks results in slight non-uniformities in the location of the various inlet and outlet nozzles

and similar nozzles on identical breakers or pole units may be slightly displaced in relation to their respective reference center lines. This means that rigid piping laid out on the basis of the manufacturer's drawing will often fail to fit up properly with the breaker tanks when connections are attempted. It, also, means that rigid piping which will fit one tank properly may not satisfactorily fit up to an apparently identical spare. It is, therefore, very desirable that all breaker oil piping, of the larger sizes, be laid out to give sufficient flexibility to permit of some variation in the location of the breaker tank nozzles.

Recently, some of the manufacturers have adopted the practice of extending the end of the oil filling pipe several inches below the normal oil level within the tank. This is done in order to give the oil a chance to partially free itself of the entrained air during the last few minutes of filling and to eliminate the trapping of additional air during the same period. It, also, reduces the chances of the formation of air bubbles when a full tank is being circulated for purification. While all of this is very commendable, it introduces the possibility of a loss of oil unless the filling valve is absolutely tight. Normal operation has led employees to regard the tight closing of a drain valve as an imperative matter. They have not, however, so regarded a filling valve. Hence, it is desirable to consider a means of venting the filling pipe at some point between the normal oil level and the filling valve. This can easily be accomplished by the insertion of a small vent valve at the highest point of the filling pipe. Care, of course, should be taken to see that the arrangement of the valve is such as not to introduce moisture into the breaker tank.

The size of circuit breaker oil piping must be a compromise between the fixed charges on the pipe and the value accruing from the ability to drain and fill a tank rapidly in an emergency. These are variables difficult to evaluate, but it is usually better to provide piping somewhat too large rather than a little too small.

The bushings on high voltage breakers are generally quite long and rather fragile particularly in cantilever strain. For this reason, considerable attention should be given the manner of completing the electrical connections to the bushings in order to protect them from damaging forces and vibrations which might be transmitted by rigid conductors.

Oil circuit breakers of any kind are, theoretically, a fire and explosion hazard and any advance toward their elimination is progress in the right direction. In recent years, much has been done in the development of very satisfactory air circuit breakers. These switches have a rather universal application on pressures below 600 volts on both, direct and alternating current. They are adaptable to all types of mounting, including truck, and may well be considered with a view to safety.

Reactors

Reactors find their principal application in the sectionalization of networks and the protection of network branches from excessive short circuit currents. When so applied, they form very effective barriers for the isolation of trouble and the limitation of dangerous electrical, mechanical and thermal effects.

Since the impedance of current limiting reactors is made up almost entirely of the inductive component, there is always a possibility that, when used in conjunction with underground cables possessing high capacity reactance, circuits approaching resonance or at least highly susceptible to destructive surges may result. Therefore, reactors should not be applied to underground circuits without detailed consideration.

At times of heavy short circuit, a reactor may produce a very intense magnetic field. This field, in conjunction with fields of other reactors can result in severe mechanical strains between the individual reactor windings and winding structures. Further than this, there is always some flux encircling a reactor in normal operation. This flux has a tendency to stray to nearby magnetic materials and set up objectionable eddy currents, which may be of sufficient magnitude to produce serious heating and a possible physical weakening in adjacent structures.

Whenever any uncertainty exists with reference to the structural details of reactor applications, the matter should be thoroughly discussed with the manufacturer in order to safeguard against the productions of abnormal forces and stray heating.

It is customary to install reactors in substantial concrete cells and since the reactor is rugged and requires little attention, there is a tendency to cut clearances to a minimum and to overlook the matter of proper ventilation. Unless reactors are very liberally designed with reference to copper, they liberate considerable heat in normal operation. Therefore, the necessity of adequate cell ventilation should always be considered and provisions made accordingly.

Choke coils are frequently used as buffers or as deflectors to divert lightning surges away from equipment and into lightning arrestor circuits. Recent investigations have shown that, unless choke coils are carefully co-ordinated with the circuit constants of the network involving the protected equipment, dangerously high voltages may be applied to the equipment terminals. Ordinarily, this condititon does not exist in the case of smaller structures where the electrostatic capacities are of no appreciable magnitude. In the case of the more extensive structures the use of choke coils will bear detailed scrutiny and, generally, should be discussed with the lightning arrester manufacturer.

Instrument Transformers

Instrument transformers are almost universally associated with high potentials on their primary side. They constitute a hazard on the assumption that the transformer insulation may at some time break down and the primary potential be communicated to the secondary circuit. For this reason, it is imperative that the secondary or low side of all instrument transformers be effectively grounded as near the transformer as possible. In some instances, the transformer ground is attached to a station ground bus and this bus depended upon as a residual or return circuit from the secondary appliances connected to the transformers. While this expedient may be suitable in some instances, it is not generally satisfactory and a common or residual lead should be carried through to the secondary instruments and again grounded somewhere in their vicinity. This arrangement provides for duplicate grounding and also elimi-

nates the possible danger resulting from opening an incorrect ground during testing and maintenance.

There has always been some question as to the advisability of fuses and protective resistors in the high side leads of potential transformers actuating voltage regulators. This question is brought about by the fact that the blowing of a fuse or the opening of a resistor immediately indicates low voltage to the regulator which instantaneously proceeds to increase the voltage on the regulated circuits. This, of course, is undesirable and may result in flashovers and equipment failures. On the other hand, the point is made that regulator potential transformers are generally connected directly to buses which may not be differentially protected, or outside the differential protection of generators. They, therefore, provide possibilities for an unrelievable short circuit in case of transformer failure. Each argument has its merits, but it would seem that the more general practice is to operate such potential transformers with neither fuses nor resistors. Serious eventualities can always be guarded against in either practice, by adequate relaying, although the additional relaying is seldom, if ever, resorted to.

Ordinarily, wound primary current transformers have sufficient mechanical strength to withstand the usual short circuits encountered in every day practice. There are, however, frequent instances where the short circuit strains are so severe that the current transformers are disrupted with varying degrees of disastrous results. The application of this type of current transformers should be made only after a detailed study of short circuit conditions, where the slightest doubt may exist as to their ability to withstand the incident strains. The dangers resulting from the mechanical failure in such current transformers can quite frequently be eliminated by specifying special bracing. This, of course, is a matter of design and should be discussed with the manufacturer prior to any definite decision.

Bushing type transformers are not subjected to appreciable mechanical strains even under conditions of the most severe short circuit and can frequently be advantageously substituted for the less rugged wound primary type.

The use of this type of transformer is somewhat limited due to the fact that its accuracy is very poor on the lower transformation ratios and may, also, be effected by the physical configuration of the core. Here again, it is highly advisable to discuss the application thoroughly with the manufacturer prior to any final choice.

Station Battery

Practically all generating and switching stations of sufficient size to justify electrically operated controls depend upon the storage battery to supply the energy necessary for actuating the switching equipment.

The choice of battery size is a matter of considerable importance since, in the last analysis, the battery is responsible for performing all necessary switching operations, even though the system may be totally de-energized through accident or for other causes. Hence, there may be times when the satisfactory performance of the battery is of vital importance.

Since the battery is primarily for switching purposes, little error, if any, is ever made in securing one of adequate capacity to handly emergency switching conditions. There is, however, a tendency to overlook the fixed load, such as pilot light, graphic instruments, carrier current telephones, etc., which may be carried by the station battery at all times. In addition to this, the matter of battery drain, due to emergency lighting, is quite often given too little attention. Thus, the selection of battery equipment should not be based on switching requirements alone, but, also, on steady drain requirements, emergency lighting requirements and any other special loads which might be supplied by the battery.

Since, as stated before, a station battery may be a vital factor in times of emergency, it is very desirable that more than one means of charging be provided and that the several charging sources be as reliable and independent of each other as possible. In considering the choice of battery charging equipment, it is not a bad idea to assume that, under some circumstances, the battery itself may be unavailable for service, and to provide at least one charging source with sufficient capacity to handle minimum switching requirements.

Most of the batteries used nowadays for switching purposes are of the acid type and various hazards are introduced by the acid electrolyte. Battery rooms, for this reason, require particular attention. When the battery is being charged, explosive gases are liberated and permanent and effective ventilation for the battery enclosure is essential to safety. In addition to this, there is always a possibility of acid containers being broken or turned over in the battery room. Any appreciable depth of acid on the floor would make correction practically impossible. Thus, battery rooms should be provided with pitched floors properly drained through vitrified pipe in order that any unexpected spillage may be immediately and effectively disposed of.

Much of the danger inherent in the ordinary glass jar acid battery may be eliminated by the use of the totally enclosed type of cell which is quite similar to the automotive battery. These batteries are now being used without the special provision of battery rooms and are being set up in operating rooms or other convenient places about the plant. These batteries do not eliminate the explosion hazard and should not be installed in small rooms without adequate ventilation.

Interlocks

A properly designed system of interlocks is probably one of the greatest guarantees of safety available for the generation, transmission and utilization of electrical energy. Interlocking, however, must be typical to each individual installation and cannot be treated with any detail in a general discussion. There are, nevertheless, one or two points which are applicable in all interlocking layouts.

Too often, in the development of interlocking schemes, the designer places himself in a position of purely preventing an act on the part of the operator. Consequently, this spirit is inherent throughout the scheme, and the resulting work stands out as a challenge to the operators and attendants. They are not slow to recognize the challenge and immediately set out to find ways and means of proving a deficiency in the designer's work. This, of course, is a dangerous attitude since methods discovered for cancelling

the interlocks may be passed on to irresponsible persons who will resort to them without full knowledge of the consequences. Wherever possible the designer of an interlocking system should deliberately attempt to convey the idea that the system is intended as a protection rather than a prohibition.

The interlocking of large systems invariably becomes extremely bulky and unwieldly even when accomplished through the simplest interlocking methods. It is not infrequent that an attempt is made to simplify the system by substituting operating orders for some particular step or sequence which might be difficult to handle if the general scheme were carried through. This is obviously a dangerous practice and should not be resorted to since it results in a loss of faith in the system itself and may foster a gradual substitution of operating orders for interlocking operations.

Transformers

Many advances have been made for the promotion of safety in transformer operation in the last few years. Most conspicuous among these are the pothead or industrial housing type, the conservator type and the inert air type.

The pothead arrangement can generally be applied to either of the latter two types previously named and has the advantage of providing totally enclosed terminals, thereby eliminating possible dangers of personal injury and short circuits.

The conservator type of transformer reduces the fire and explosion hazards to a minimum by keeping the tank completely filled with oil at all times, precluding the likelihood of any combustible or explosive mixture within the tank. It further acts to preserve the quality of oil by exposing only a small surface to the atmosphere and this surface is usually at a temperature much below that necessary for rapid deterioration.

Since all volume changes within the conservator type transformer are taken up by the conservator tank, there is always some flow through the inter tank pipe due to changes in both internal and external temperatures. If this pipe happens to be small in diameter, there is a possibility that certain grades of oil may become chilled to the congealing point within the pipe, producing an effective barrier between the two tanks. Should this happen and a sudden increase in temperature take place within the transformer, there is a possibility that the explosion diaphragm, provided where conservators are used, may be broken due to an increase in internal pressure. The fracture of the diaphragm would proably take place quite passively and its occurence may pass unnoticed for some time. Under such conditions, there would be a possibility for the transformer to gain considerable moisture due to the defective diaphragm. The chances of such difficulties generally seem remote but they are sufficiently great to justify the provision of an inter tank connection of sufficient size or the installation of heat insulation on the inter tank pipe when conservators are used in cold climates.

While the conservator tank is supposed to reduce explosions to a minimum, the presence of the explosion diaphragm may always be taken as an indication of their possibility. Hence, care should be taken to see that the diaphragms are always pointed in a direction such that the ejection of oil or flame through the diaphragm pipe will do a minimum of damage.

The inert air type of transformer reduces fire and explosion hazards by filling with nitrogen the spaces which would ordinarily be occupied by air. Since this gas does not support combustion and has little or no tendency to produce sludging, the dangers of fire and explosion as well as those incident to oil deterioration are materially lessened.

The introduction of tap changers of both, the deenergized and under load type, has introduced valuable safety features in transformer operation. These tap changes eliminate practically all of the dangers common to tap changing with the old terminal board arrangement and are generally well worth their extra cost when tap changing is anticipated, even as an infrequent event.

In the last analysis, the load capacity of the transformer is not determined by the energy losses alone, but rather by the combination of the energy losses and the idle temperature. Thus, the final criterion of loading is the actual temperature at the hottest spot and not the current carried or the external ambient. For this reason, the surest means of ascertaining the safety of a transformer under load rests in the use of a temperature indicating device. Such a device, made to accurately show the temperature of the hottest spot, it is undoubtedly the safest indication of the transformer's true loading condition. If it is impossible to use a temperature indicating device which will accurately show the hottest spot, the next best arrangement is a thermometer of some kind which will show the oil temperature at the top of the transformer. Such a thermometer cannot be accepted as an ultimate criterion, and proper allowances must be made for the loss of temperature between the hottest spot and the oil surface. Nevertheless, thermometers properly applied and correctly interpreted, are probably the surest safeguard against destruction form overloading.

Whenever water cooled transformers are installed in climates where freezing temperatures are expected, considerable care should be given to the layout of the cooling piping system in order to insure that it will not become frozen and thereby cut off the circulating water. This admonition seems perfectly obvious, yet for some reason or other, the possibility of freezing is quite frequently overlooked and the necessary provisions are not made until after the transformers are installed and in operation.

The previous remarks with reference to flexible oil connections for oil circuit breakers apply equally forcibly to transformers with the additional caution that the water connections should also be made sufficiently flexible to close easily and quickly even though the transformer nozzles may be somewhat out of alignment.

It is usual to protect transformers against destruction from internal faults by means of differential relaying. At first thought it would appear that low energy differential relays should be used in an application of this kind. Experience, however, has shown that the low energy relay is usually too sensitive for transformer differentials and that transient inequalities of current in the two windings will frequently disconnect the transformers during switching operations or sudden changes of loads. For this reason, it

is usually better to use the standard type of relay in this application.

Occasionally a situation is encountered where constant current transformers are to be applied to loads which are expected to increase very rapidly. They are, therefore, chosen with capacities capable of handling the ultimate anticipated loads and may be put into service on loads which are only a small percentage of their name plate rating capacity. Under such conditions, the transformer may fail due to a complication of reasons, apparently directly traceable to under loading. The exact mechanism of such failures does not seem to be generally understood at this time but, when constant current transformers are expected to operate at loads much less than 50% of their rated capacity, the matter should be taken up in detail with the manufacturer in order to insure that the application is entirely correct.

Ground System

General observations seem to indicate that the station ground system is not given the attention its importance justifies, particularly in some of the larger projects. In order that a ground system can function to its maximum efficiency, its design and layout should be based upon accurate calculations These calculations should not only indicate the maximum current to ground, but also the maximum current to be expected from the failure of the individual pieces of equipment and various insulators.

With this information as a basis, the ground system should be laid out with a view to carrying maximum fault current from any piece of equipment or insulator to ground without producing ohmic drops which may raise remote and exposed sections of the ground system to dangerously high potentials above the earth. The operation of the system in emergencies should be anticipated and sections of bus likely to be elevated to considerable potential above ground should be adequately insulated for the protection against personal injury. This, of course, assumes that the potentials attained are insufficient to damage equipment which may normally operate with one or all windings grounded. The better practice is the use of copper of sufficient cross section to insure that no portion of the bus will, under any conditions, be raised to a potential which will constitute a hazard to either person or equipment. It is not infrequent that the total weight of copper in a ground system can be somewhat decreased by the use of a greater footage of smaller cross section, thoroughly interconnected with branches looped back to mains wherever possible.

Where grounding systems are enclosed within steel buildings, it is advisable to bond the copper to the building steel as frequently as convenient without introducing undue expense. Such bonds should be assigned no carrying capacity in the design of the ground system and should be considered only as maintaining the individual sections of the building steel at the same potential as that of the adjacent ground copper. This eliminates the possibility of dangerous voltages between building steel and ground system.

In the past there has been a decided tendency to isolate station and lightning arrester grounds, one from the other. This practice is now being questioned and there is a present trend toward the tying of all equipment to a common ground. This, of course, assumes that the ground system has been carefully developed and so interconnected that the potential gradients produced by lightning arrester discharges are kept below a dangerous point by the use of ample copper sizes and numerous parallel paths.

Some of the larger systems have recently attempted to assign a distinctive protective duty to certain sections of the ground bus system. These sections are usually known as fault buses and have current transformers inserted at predetermined points in their runs. The transformers are connected to suitable relays which are so inter-related with other relays that a higher degree of selective tripping may be obtained. Occasionally, arrangements of this kind have failed to perform in accordance with expectations due to insufficient insulation on the fault buses resulting in unexpected current drains ahead of the transformers. Thus, the total current through the transformer was not the total fault current and the relay operation was erratic and uncertain. These past experiences clearly indicate that the dispersion of current, along an uninsulated bus, may be considerable and that sections of ground systems, used as fault buses, should be adequately insulated.

Where provisions are made for the deliberate grounding of de-energized equipment, the safest system is probably that of completing the ground through a remotely controlled oil circuit breaker. In an arrangement of this kind, a double throw disconnecting switch is inserted between the breaker and the source and connected blade to breaker, clip to bus and clip to ground. This system permits the operator to stand clear when the ground circuit is finally completed and largely eliminates the possibility of personal injury in the event that an incorrect ground is established.

During the development of any ground system, the equipment layout should be studied with a view to ascertaining the individual pieces to which temporary grounds might be attached in routine inspection and maintenance. Provisions should then be made to expose short sections of the ground bus in the immediate vicinity of all such equipment. The location of the exposure and form of the bus should be such that it may not be easily contacted in the performance of normal duties, but is freely accessible for the quick and secure attachment of temporary ground connections when necessary.

Inasmuch as arrangements for temporary attachments to the grounding system are elements of the design, they should be accompanied by the provision for an adequate number of flexible conductors which can be quickly and surely attached to the exposed sections of the ground bus specifically furnished for that purpose.

It seems superfluous to call attention to the necessity of frame, base and case grounds, but this is a matter which is generally everybody's business and, hence, nobody's responsibility. For this reason all design drawings should specifically show, or at least note, the approximate location and number of frame and case grounds for all equipment and instruments.

Provision should always be made for the protection of the operator in the case of hand actuated disconnecting switches wherein the linkage between the hand operating mechanism and the switch is accomplished by metallic members. This protection may

be effected by the expedient of requiring the operator to stand on an insulated bench or a properly grounded metallic platform. In either case, the hand operating devices should be adequately grounded, and the bench or platform made a permanent part of the structure. This will insure their use at all times and will eliminate the necessity of depending upon the operator for his own protection. In cases where the grounded metallic platform is employed, it should not only be effectively grounded, but should be adequately bonded to the operating handle. The carrying capacity of the bond should be such that the maximum current flowing over it will not produce a dangerous resistance drop between points of contact of the operator's hands and feet.

Many of the modern outdoor disconnecting switches are operated by rotating shafts between the hand operating mechanism and the switch. It is not infrequent that these shafts may make many revolutions in a single switch operation and it becomes troublesome to properly ground the rotating shaft, adjacent to the hand wheel. This difficulty has been overcome in some instances by passing the operating shaft through a stationary, metallic annular bowl and securing to the shaft a rotating casting in the form of an annular protusion which extends into the stationary depression and, at the same time, houses it against the entrance of rain and snow. When the rotating casting is bonded to the operating pipe, the stationary depression filled with mercury and the stationary casting grounded, the operating shaft is effectively drained by a device which should be highly efficient at all times. Since mercury has a tendency to disintegrate most metals, both the stationary and rotating contacts should be made of a good grade of cast iron and left ungalvanized.

Particular care should be exercised to provide for proper grounding and electrical drainage in extensive bus structures operated at voltages of 45 kv. and above to avoid the possibility of isolated bus sections being raised to dangerous potentials by electrostatic induction. It is, therefore, advisable to provide a permanent means for grounding and draining all sections rather than to depend upon the operators or maintenance forces to supply and install temporary connections.

Switchboards

The switchboard may be considered as the nerve center of the plant or system and is entitled to a most thorough consideration with reference to safety. Unfortunately, switchboards are so varied in their purpose and application that it is impossible to discuss them in generalities. This applies particularly to the numerous systems of relay protection.

The various types of switchboards in use at the present time may be classified as live front and back, dead front and dead front and back. These three general classes have been stated in their order of prevalence and in the inverse order of their probable safety.

The design of the dead front and dead front and back boards is complicated by the fact that many of the parts originally mounted on the front part of the board are carried to and must be disposed of in the rear. This invariably means crowding and particular attention must be paid to the maintenance of adequate clearances on this type of board.

At the present time steel panels are becoming quite general for switchboards and their use, with proper care, introduces few, if any, hazards over those encountered with the semi-insulating panel materials. The application of air circuit breakers on steel panels must be executed with considerable precaution to prevent the possibility of arcs straying into the steel and being grounded on the panels.

Irrespective of the type of board or quality of panel material, there are several general safety measures which deserve attention in the design of any switchboard.

There is always a tendency to over-crowd both instruments and wiring on practically all boards. This tendency is perfectly natural and unless carefully guarded against, can result only in insufficient clearances for inspection and maintenance. The importance of liberal clearance on the live side of any switchboard cannot be over-emphasized.

Probably one of the greatest safeguards to service so far as switchboards are concerned is the proper and permanent marking of all terminals and connections. This practice materially eliminates errors in checking and maintenance, and makes incorrect operation a matter of carelessness rather than ignorance or uncertainty.

The use of a single common ground return wire is a very common practice in switchboard connections at the present time. As a rule, the ground or residual leads from various groups of instruments are consolidated as near their sources as possible and carried on a single insulated conductor to the panel ground wire by the most direct route. This consolidation makes checking and the location of trouble extremely difficult since it is sometimes practically impossible to trace ground or residual circuits back to their originating studs. It, also, has the disadvantage of making possible the unintentional opening of several ground circuits by the premeditated severance of a specific lead. All of this is conducive to confusion and may, under certain conditions, create a definite hazard. This difficulty can easily be eliminated by carrying a single small uninsulated ground bus up the back of each panel and conveying the residual for each particular circuit to the bus by a separate conductor.

It is quite common to install operating buses behind switchboards, in a horizontal position. These buses may be flexible or rigid and insulated or uninsulated but, in any event, it would seem that the horizontal arrangement should be used only as a last resort. Such disposition of buses has the disadvantage of displaying the greatest surface to falling tools and parts as well as providing tool shelves for the use of careless workmen. The fact that the buses are insulated does not necessarily mean that the insulation may not be damaged and the careless placing of a tool may result in serious personal injury or a complete shut-down. It is, therefore, advisable to arrange operating buses in vertical rows wherever possible. This arrangement, of course, is open to the argument that the vertical rows have a tendency to obstruct work on studs and wiring which may be located behind the buses. The objection can generally be overcome by a careful study of the situation and if necessary, supporting the buses on the

upper horizontal braces or on brackets at a point sufficiently remote from the back of the board to permit easy access to all back mounted wiring and equipment.

In times of emergencies, the trip circuits are all important. Hence, every effort should be made to insure the certain maintenance of their continuity. One of the greatest aids in this direction is the supervisory trip circuit connection, by which the trip circuit is fed thru the lamp indicating the closed position of the main switch. Thus, a failure of the trip circuit is immediately shown by the extinguishing of the light indicating the closed position of a breaker known to be closed. This arrangement is sometimes extended to include both the closed and open indicating lights and either system is worthy of consideration.

There have been some objections to supervisory trip circuits on the grounds that a short in the indicating lamp will trip the supervised breaker. This objection has been quite satisfactorily removed by the insertion of sufficient resistance in the immediate lamp circuit to prevent accidental tripping.

The fusing of tripping circuits should be carried out with greatest care and, in general, fuses should be of sufficient capacity to open only upon the occurrence of a dead short circuit. Smaller fuses may open for mechanical or irrelevant reasons and, in the absence of supervisory tripping, may pass unnoticed, thus leaving a circuit unprotected.

Ill-considered connections and arrangements of potential and synchronizing buses, in some instances, may result in back feeds whereby a normally dead circuit may be energized from its own potential transformer by secondary coupling with some live circuit. This is a condition, not always obvious, which may produce highly disastrous results and should be guarded against by the utmost care in the checking of wiring diagrams.

The continually increasing trend toward the routine testing of all relays and metering equipment has materially increased the danger of outages due to incorrect test connections and operations. This hazard can be greatly reduced by the anticipation of probable routine tests which will be required and the initial installation of test switches and connections specifically designed to eliminate the possibilities of incorrect testing operations.

The employment of differential tripping for generators does not prevent the occurrence of internal breakdowns, but does naterially alleviate the results which they may produce. On first thought, in the consideration of differential operation, it might be assumed that the mere opening of the main breaker would be sufficient. This is not generally the case and provisions should usually be made for opening the main switch, the field switch and the neutral switch, if used, in the order named. In some instances it might be desirable to carry the sequence even further and operate to remove the motive power supplied to the generator. This is not usually necessary and the desired results can generally be obtained by carrying through the sequence first stated.

Occasion frequently arises where considerable expense can be saved thru the elimination of potential transformers by resorting to what is known as a potential throw over. In this scheme, the potential supplied to relays, instruments, etc., must be transferred from an outgoing to an incoming bus or machine while both are energized; otherwise, the supply to the instruments will be interrupted. In many types of relays, potential failure results in immediate operation and the entire system may be put out of commission by the careless or ignorant handling of the potential throw over. Before such an arrangement is finally accepted, a little thought on its probable consequences may be worth many times the expected saving in transformers.

Induction Regulators

The improper manipulation of induction regulators may lead to all kinds of trouble. This does not particularly apply when the connections are such that the regulator and its associated line or feeder are removed from service simultaneously by a single switch. Such an arrangement, however, is not always satisfactory and means must sometimes be provided for taking a regulator out of commission or substituting a spare regulator without service interruption. Under such conditions, it is worthwhile to expend considerable effort to insure the proper handling of the equipment.

When a regulator is to be taken out of service without de-energizing the regulated load, the rotor should first be run to the neutral position and the secondary short circuited. The primary circuit should then be opened. This, of course, assumes that the regulator is so installed that after the foregoing operations are completed, disconnects may be opened and the regulator isolated from all wiring without service interruption.

It is practically impossible, or at least not economical, to make provisions for insuring that the secondary is run to the neutral position. If this is not done, however, the short circuiting of that winding may result in exceedingly high circulating currents which may wreck the winding or the entire regulator.

If, through error, the primary is opened prior to the shorting of the secondary, the regulator will take on the characteristics of a current transformer and dangerously high potentials may be impressed across the primary opening. These potentials may attain such values as to endanger the insulation of the primary and that of other circuits conductively connected to it.

Since the principal of operation of the induction regulator necessitates relatively large air gaps and the magnetically uneconomical use of the iron, the primary must necessarily be highly inductive. This high inductance leads to further difficulties in the manipulation of regulators and consideration must be given to the manner of disconnecting the primary. On smaller regulators a disconnecting switch is usually sufficient but, on the higher capacities, a disconnecting switch quickly opened, results in a highly accelerated rate of flux collapse which may produce dangerously high voltage and destructive arcs across the switch opening. Therefore, it is wise to consider the application of an oil circuit breaker for the interruption of the primary circuit, although the use of such a breaker may not be necessary in many cases.

Since induction regulators are generally oil insulated and frequently water cooled, the previous remarks concerning flexible conductor and pipe con-

nections with reference to oil switches and transformers, apply equally well to regulators.

Cables and Conduit

Conductor and cable failures for purely electrical causes, due to the choice of improper types of insulations are rather infrequent but such failures have resulted from attempting to operate particular insulations at idle temperatures sufficiently high to cause a deterioration of the insulating material. The consideration of idle temperature is of much importance in the selection of wire and cable insulations. This point is seldom overlooked in the case of a larger and more important conductors, but is frequently given no thought in the instance of low voltage wiring, such as control and lighting cables.

The precautions to be observed in the bonding and draining of lead sheath cables are generally adhered to and little trouble is experienced from destructive and dangerous surface currents and voltages. Similar precautions are often assigned too little importance or completely ignored in the case of the installation of braid covered conductors when used at high potentials. The prevailing idea seems to be that the absence of the lead sheath eliminates all difficulties which might be inherent on the exterior of the cable. This assumption is erroneous and it is not infrequent that dangerously high potentials are found on the braided covering of cables and conductors carrying energy at high potentials. This is particularly noticeable when such cables are installed on insulators or in semi-insulating conduits. The difficulties usually arise from the fact that the braids are generally neither perfect insulators nor good conductors. The result is that certain sections of the braid may become sufficiently conducting to collect a charge while adjacent sections are sufficiently insulating to prevent its drainage. This condition, besides being dangerous to life, will frequently cause an insulation deterioration at points where cables may pass over one another with only a slight air gap. For these reasons, all braided cables and conductors to be operated at the higher potentials should be carefully discussed with the manufacturer in order to ascertain that the application is correct and to secure recommendations for the adequate draining of charges which may be induced on the braid.

Another difficulty encountered in the use of braided conductors at high voltages is the possibility of concentrations of electrostatic strains over relatively small areas of insulation. Frequently, braided conductors are installed in semi-insulating conduits. Under such conditions, a grounded conductor in the immediate vicinity of the conduit is likely to set up a high electrostatic stress between itself and the cable core, which may result in insulation failure. This does not mean that all installations of braid covered conductors in non-conducting conduit constitutes a hazard. In many instances, fibre conduit is laid directly on the reinforcement in concrete floors and no difficulty is experienced. This is probably accounted for by the fact that the reinforcing is so close together that there is a merging of the stresses which results in a more general distribution and, consequently, a diminution of the flux densities. Difficulties of this kind are, therefore, only to be expected where the ground conductors contact with the conduit at only infrequent intervals throughout relatively long runs.

Practically all of the insulating materials used at the present time for conductors and cables have radically different mechanical qualities and are variously effected physically by mechanical manipulation at different temperatures. Since this is the case, it is good judgment, in the absence of detailed familiarity with the product, to anticipate any extreme temperatures at which the conductors may be installed and to consult the manufacturer as to the best method for their handling. Under similar conditions, it is, also, advisable to ascertain the minimum permissible bending radii at normal as well as extreme temperatures.

There is one precaution in connection with the design of conduit and cable systems which merits attention and is quite frequently overlooked. This is the matter of protecting conduit runs against the entrance of rats, mice and other small animals, the activities of which have been known to result in several insulation failures. Apparently this is a small matter but the cost of screening or otherwise closing the conduit openings is usually an excellent investment.

Lightning Arresters

Lightning arresters, like all other conducting equipment, have a very definite maximum current carrying capacity. When this limit is exceeded, the arrester not only ceases to function properly, but is usually totally destroyed. Thus, the application of lightning arresters should be carefully coordinated not only with the nominal operating voltage and the maximum rated voltages of the equipment to be protected but also with the synchronous capacity available to deliver current to ground through the arrester.

The application of lightning arresters to water wheel generators deserves particular attention due to the fact that generators of this type are very liable to overspeed on loss of load. In some cases, terminal voltages, due to generator speed increase, reach values sufficient to flashover the arrester gap, establishing a purely dynamic gap arc and passing excessive currents to ground through the arrester. This condition is frequently made more acute when the lightning arresters are connected on the high side of a transformer bank feeding a considerable length of high voltage transmission line from any generator unit having a sluggish governor action. Under these conditions, a loss of far end load not only initiates over-speeding in the generator but removes what may have been a lagging load of low power factor, and substitutes in its place the leading charging current of the line. Here, there is a pronounced compounding effect and the pressure at the terminals of the arrester is a composite voltage consisting of the generator overspeed voltage plus the magnetizing effect of the leading current in the generator windings, and in addition to this, the voltage component produced by the leading current traversing the generator and transformer windings. Thus, the rate of increase in voltage is cumulative and, in the absence of flashovers, is limited only by the relatively slow retarding effect of the governor and the increase in lagging exciting current drawn by the transformers at over-voltages. Based on the performance of mod-

ern equipment, this voltage rise can easily take place and the arrester be destroyed by a purely dynamic current flow before the retardants can become effective. It is essential that conditions similar to those just described, be thoroughly and carefully examined before making a final choice in lightning arresters.

Where lightning arresters are installed out of doors, there seems to be no general practice with reference to their enclosures. The arresters are usually fenced when installed by themselves and in the absence of other equipment. In many cases, particularly with reference to outdoor switch yards, the yard itself is adequately fenced and the arresters left without enclosures. This is probably done on the assumption that anyone authorized to enter the yard, knows the dangers and hazards resulting from contact with the arresters. This assumption is probably valid in most cases, but the trifling cost of properly fencing arresters, even when within the outer enclosure, can easily be written off as good insurance.

Conclusion

In retrospect, it would seem that modern electrical structures are generally safe with reference to normal operating conditions and that most of the existing or potential hazards result from a failure to properly evaluate the apparently minor points and to accurately anticipate the unexpected.

Efficiency versus Economy

By H. G. EBDON*

Advancements made in the burning of fuel and the generation of steam have been so widely advertised that in a great many cases high thermal efficiency plants are being considered and installed without justification. On the other hand there are as many cases where full advantage is not taken of the more efficient equipment that has been developed. A few of the smaller industrial plants in trying to approach Central Station operating results lose sight of the fact that Public Utilities work on a much lower basis

H. G. EBDON

of return; that Central Stations have a comparatively high load factor and are tied in with other stations of the system thereby minimizing the amount of spare equipment necessary.

The enthusiasm of the equipment manufacturers selling a particular piece of apparatus forming only a part of the complete steam generating equipment helps to keep the first condition alive as they are not particularly interested in the net return of the complete unit; their interest being limited to installing a workable and satisfactory job only, as far as their individual equipment is concerned.

The stoker man tells you about high maintenance and slagging difficulties that can be expected with pulverized coal; also the troubles with wet coal. The pulverized fuel man claims that stoker equipment is out of date and you will be tied down to some definite grade of coal, for which a premium has to be paid. The air heater enthusiast points out that economizers played an important part before the days of the extraction turbine but since then the air heater is supreme in the recovery of heat from waste gas, and the economizer expert comes right back claiming high furnace and equipment maintenance with air heaters; also inaccessabiloity for cleaning. To complicate matters each will substantiate his statements with records at some particular plant.

We all know that there is a proper place for each of the different types of apparatus, but it is quite a problem to work out the most suitable application unless a competent consulting engineer is employed. Some of the larger manufacturing companies with a complete line of equipment are in a position to make unbiased analysis of plant conditions as they are not limited to any particular type of burning or heat absorbing equipment, and the purchasers are beginning to take more advantage of this service.

Previously, separate specifications were sent to all manufacturers in the field, and as 250% of rating was considered good practice, the boilers were specified on this basis; although it may not have been an economical point of operation.

The boiler manufacturer would make exit gas temperature guarantees that were qualified by a gas analysis of 15% CO_2. The stoker or pulverized fuel manufacturer would predicate his efficiencies on certain boiler exit gas temperatures, and the air heater manufacturer would base his guarantees on a certain amount of combustion air being passed thru the heater. In checking up the operating costs and fixed charges the engineer would find that the total expenditure was warranted and equipment would be purchased.

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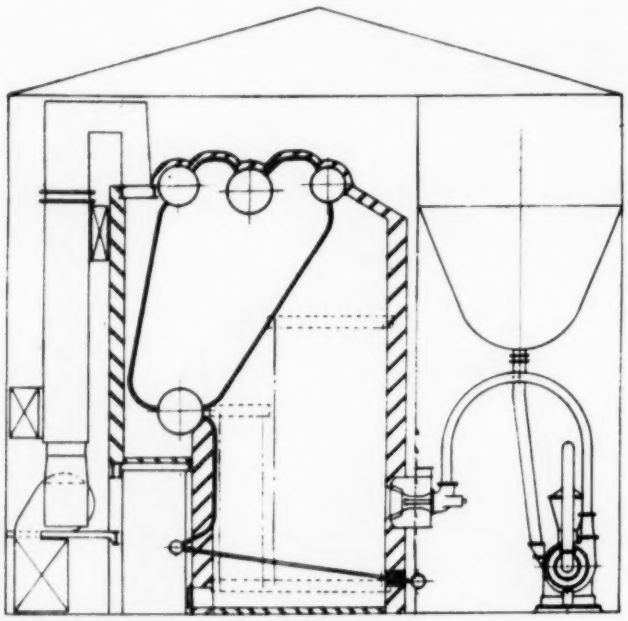
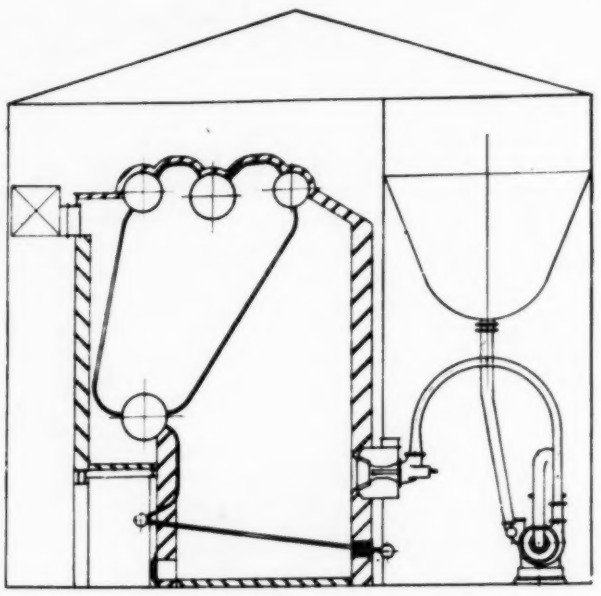
After the equipment was installed acceptance tests were run and actual efficiencies were perhaps considerably below those guaranteed, but the boiler contractor is not liable because the stoker did not deliver 15% CO_2. The stoker contractor cannot be held because the boiler did not absorb the amount of heat on which his efficiency was based. Also, the setting leaked to some extent and a lesser amount of combustion air passed thru the heater. In each case the manufacturer predicated his guarantees on test limits:—conditions that cannot be obtained in practice, and on the basis of actual overall figures the equipment may not be the profitable investment originally estimated. This illustrates one of the most important points in making an economical set up for a proposed power plant—that is; correlating the performance guarantees of the individual manufacturers.

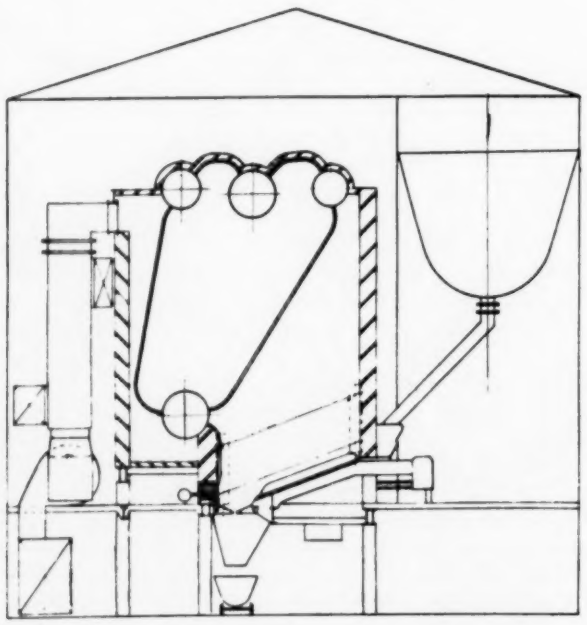
Another point of equal importance is the selection and proportioning of the number and size of units. Although 250% continuous operation is considered commercially practical, it does not necessarily mean that an efficient and economical plant cannot be designed for lower ratings. In order to show the effect of coal cost and capacity factor, four different plant designs have been prepared showing the relation of initial investment and operating costs. The general design is shown in Figure 1, and a comparison is given between stoker and pulverized fuel firing, as well as high and low ratings. All are based on a plant size of 100,000 lbs. of steam per hour.



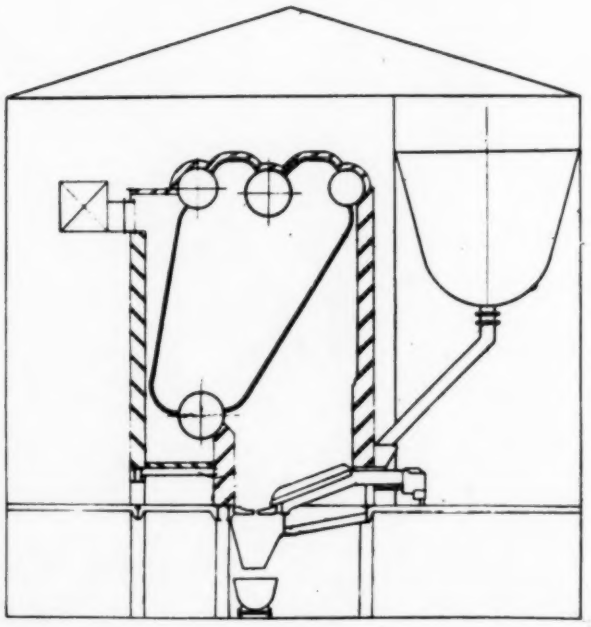
Case "A"



Case "B"



Case "C"



Case "D"

Case A covers a three boiler arrangement using pulverized coal at about 300% of rating. Water walls are used as well as air heaters, and the furnace volume is kept down to within reasonable limits, allowing a heat release of 20,000 B.t.u. per cubic foot.

Case B covers four boilers at 188% of rating with a furnace designed for 16,000 B.t.u. per cubic foot and both water walls and air heaters have been eliminated, although water screens are used to minimize ashpit slagging.

Case C is similar to Case A, except that multiple retort stokers are used, and Case D covers four stoker fired units with solid walls and without air heaters.

In all cases one boiler is kept as a spare and assumed steam conditions are: 250 lb. pressure, 150°F. superheat, and 210° feed water.

Table 1 shows the operating performance and first cost of each plant, and Table 2 shows the yearly operating costs. These operating costs are given for four conditions: 3000 hours per year operation and $3.00 coal, 5000 hours operation and $3.00 coal, 3000 hours operation and $5.00 coal, and 5000 hours operation with $5.00 coal.

The figures given in Table 1 are comparatively accurate and show the relative costs of equipment being sold by one manufacturer. In working up this tabulation no attempt was made to prove anything except that there is a proper place for all classes of apparatus and no one class is the solution of all conditions. The size of plant was picked at random, representing a fair average of industrial plants. In this particular instance, using a fixed coal cost, stokers show up more favorable than pulverized fuel. But in a large number of cases slack coal suitable for pulverized fuel operation can be purchased at a lower price than properly sized stoker fuel, and if we assume a differential of $1.00 per ton in favor of coal for the pulverized fuel plant, we find that a pulverized fuel installation is much more economical than stokers. The plant with the highest thermal efficiency shows the highest operating cost with the low priced coal and low capacity factor, but it is apparent that as either or both factors increase it is easier to justify the higher initial investment for more efficient equipment.

TABLE 1.

	Pulverized Coal Fired		Stoker Fired	
Number of Boilers	3	4	3	4
Building Volume	183000	190000	171000	192000
No. of Boilers on Line	2	3	2	3
No. of Boilers Spare	1	1	1	1
Per Cent Rating (Boiler Only)	296	188	282	188
Boiler Heating Surface	5600	5880	5880	5880
Water Wall Heating Surface	600	--	--	--
Air Heater Surface	7000	--	5000	--
Combustion Rate	20000 B.t.u.	16000 B.t.u.	43#	36#
Gas Temp. Leaving Boiler	630	545	630	550
Gas Temp. Leaving Air Heater	370	--	430	--
Test Efficiency	84	79.5	82	78.5
Operating Efficiency	82	77.5	78	74.5
COST				
Building	$55000	$57000	$51300	$57600
Boilers	30000	41000	31000	41000
Superheaters	8500	11600	8700	11600
Soot Blowers	2700	3700	2700	3700
Air Heaters	15000	--	11000	--
Fan Equipment	13000	8000	13000	8000
Ducts	12500	6000	12500	6000
Water Walls	27800	10000	14400	--
Setting, Steel Work and Hoppers	36800	46400	24000	32000
Coal Burning Equipment	34200	39500	26700	29600
Breeching and Stacks	4000	10000	4000	10000
TOTAL COST	$239500	$233200	$199370	$199500

TABLE 2.

OPERATING COST $3.00 COAL—3000 HOURS OPERATION PER YEAR				
Fuel Cost	$ 45300	$ 47700	$ 47400	$ 49600
Labor	20000	20000	24000	24000
Maintenance	1530	2860	2240	3640
Power	7500	4370	5600	2240
Fixed Charges 25%	59875	58300	49842	49875
TOTAL COST	$134205	$133230	$129082	$129355
OPERATING COST $3.00 COAL—5000 HOURS OPERATION PER YEAR				
Fuel Cost	$ 75500	$ 79500	$ 79000	$ 82700
Labor	24000	24000	30000	30000
Maintenance	2550	4770	3730	6060
Power	12500	7300	9600	3730
Fixed Charges 25%	59875	58300	49842	49875
TOTAL COST	$174425	$173870	$172172	$172365
OPERATING COST $5.00 COAL—5000 HOURS OPERATION PER YEAR				
Fuel Cost	$ 75500	$ 79500	$ 79000	$ 82700
Labor	20000	20000	24000	24000
Maintenance	1530	2860	2240	3640
Power	7500	4370	5600	2240
Fixed Charges 25%	59875	58300	49842	49875
TOTAL COST	$164405	$165030	$160682	$162455
OPERATING COST $5.00 COAL—5000 HOURS OPERATION PER YEAR				
Fuel Cost	$126000	$132500	$131600	$137700
Labor	24000	24000	30000	30000
Maintenance	2550	4770	3730	6060
Power	12500	7300	9600	3730
Fixed Charges 25%	59875	58300	49842	49875
TOTAL COST	$224925	$226870	$224772	$227365

The maintenance and labor costs in Table 2 are merely relative and do not necessarily represent actual costs as they will vary with location of plant and labor conditions. The power cost is quite an item and is often overlooked.

In both Cases A and C where air heaters are used it was necessary to use an induced draft fan due to the low final gas temperature and the increased resistance. The power required for the forced draft fan was increased approximately 25%, and the total increased power cost as well as the fixed charges on the induced draft fan and additional insulated ductwork should be charged up to the air heater application. In some plants using turbine exhaust for process work, power is almost a by product and does not have to be seriously considered.

Although this paper has dealt with plant conditions in the average industrial field, it applies in general to all steam raising plants including those in the steel industry. Heretofore the steel mill power plant has had a haphazard growth as there was a surplus of blast furnace gas, but developments in electrification have put the power requirements beyond that obtainable with the blast furnace gas supply and more efficient equipment is required to get the most out of the fuel. As the demand for power has increased it means adding coal burning units to carry the load, and the newer installations are designed for both blast furnace gas and coal in the same furnaces.

The Youngstown Sheet & Tube Company is installing 5—2000 H.P. boilers, each capable of producing the steam demands with either blast furnace gas or pulverized fuel. The Gulf States Steel Company at Alabama City has a new steam plant with 4—900 H. P. boilers of similar design.

The Bethlehem Steel Company at Sparrow's Point has 2—1300 H.P. units as well as two steam generators for both types of firing, and the steam generators have complete water cooling on all four sides without any refractory exposed to the furnace. Each of these units deliver approximately 100,000 lbs. of steam with blast furnace gas, and the furnace volume is only 5000 cubic feet. Both air heaters and economizers are installed. The results at this plant have exploded the theory that reflected heat from refractories is necessary to maintain ignition and high CO_2.

The Inland Steel Company is about to extend their plant with 1790 H.P. boilers and economizers. Water walls will be installed and pulverized coal will be used to take the fluctuations.

This indicates the trend of improvements necessary in the power plant to cut production costs, and while the generation of power is only an auxiliary operation it represents quite a percentage of the total cost. The capacity factor of a steel mill power plant running 24 hours a day affords a real opportunity to justify highly efficient equipment. Of course, it is necessary to go thru the same stages of economical proportioning and selection as set forth in the first part of this paper. But even after this has been established some leeway should be allowed the manufacturers in order that they may take advantage of their individual shop facilities or features of design in preparing their bid.

After the bids have been received the real work of the purchasing engineer begins and the proper valuation of the competitive bids is quite a problem. Several methods have been advanced in the determination of economic value, but in most cases they have proved impractical. Manufacturers can become overly optimistic with regard to capacities and efficiencies, especially as few plants are equipped to accurately check guaranteed performance, and such a condition cannot be corrected in fixed formulas of valuation. This makes it necessary to allow a credit for something that does not show up in the price and that is the standing and accomplishment of the manufacturer in his own industry and his service organization. The least number of contracts that can be let on a particular job is also of importance. There is a sufficient number of manufacturers in the power plant field capable of handling complete fuel burning and steam generating units to get competitive bids and with one contract the co-ordination of equipment is simplified; the approval of drawings facilitated; the proper timing of shipments is assured; erection work and the starting of the apparatus are expedited, and, one set of guarantees confine to one manufacturer the responsibility of the performance of each individual element and the overall performance of the complete unit.

Selecting Electrical Equipment

By L. A. UMANSKY†

There is an old, well known story about an executive who decided to select himself and to buy an electric generator, disregarding the advice of his engineering staff. He boasted afterwards that he actually purchased a 100% power factor machine for less money than a mere 80% power factor generator, favored for some reasons by his engineers. We are apt to smile every time this story is being told. "Nowadays" we say with a certain feeling of superiority, "such things are not apt to happen; the engineer's place in industry is fully recognized and his opinion is asked on all such matters."

This, undoubtedly, is true. It is equally true that this greater trust involves a correspondingly greater responsibility. And, so I think that this is the proper place and the proper time, at this engineering convention, to ask ourselves, quite honestly and without flattery: Do we exercise to the full extent our privilege of passing judgment whenever an electrical apparatus is purchased? Are we not apt to make some fundamental mistakes, not as obvious as the one in the story just told, but which may differe from it only in a degree, and not in kind?

A correct selection of electrical machinery, on the basis of the data conventionally submitted with the most complete proposals, is a much harder task than may be at first imagined. It is, in this sense, so hard indeed that it may easily become a mere pretense. In saying so I do not mean to cast any reflection on those engineers who are engaged from time to time in buying the equipment. Quite to the contrary, I wish to emphasize the difficulty of their task, the handicaps under which they are working and the futility of the many selective methods now employed.

This statement may be considered as a challenge. It certainly requires explanation. This paper is intended to start discussions, arguments and, of course, thinking on the whole subject.

I believe that my thesis will be more clearly presented if I will discuss it from your standpoint. That is, I will assume in this hypothetical case that I am not connected in any way or form with any electrical manufacturer, but that I, let us say, run an electrical department in a steel mill.

I will further assume that I must select and purchase an electrical equipment for a new rolling mill which is being installed at my plant. This narrows down the discussion, but makes the case much clearer. Of course, the same reasoning may be ap-

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plied, with minor changes in detail but not in substance, to the selection of other kind of equipment.

Let my rolling mill require several a-c. and d-c. motors, motor generator sets, switchgear and control. I have specified the capacity and speed range of the several drives and have defined the rating of the motor generators; of course, I have explicitly stated the required temperature rise and the overload capacity. The desired general scheme of operations is also explained in my request for bids. The capacity of oil circuit breakers, etc., is stipulated. In other words, everything humanly possible is done to receive several bids, properly prepared and comparable on the same basis.

And then, after a certain time, I become the happy possessor of several proposals, more or less voluminous, more or less explicit, and I sit at my desk, anxious to find out which proposal is the best one.

I may start with the easiest part first. The

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switchgear and control equipment is the one which may be more readily analyzed and compared. After all, this equipment is usually made up of devices not designed nor built specially for my installation; oil circuit breakers, contactors, relays, meters, etc., are of the makers' standard lines. For instance, if the manufacturer X offers me his "type ABC" oil circuit breaker, of certain interrupting and current carrying capacity, I usually have a right to take his guaranty at its face value; I can do so not only because I may have faith in this particular manufacturer, but primarily because similar breakers were previously built and have passed the acid test of usage. In other words, I am basing my trust in this respect not so much on my personal judgment but on facts recognized by the engineering profession at large.

Of course, I may examine the construction of the breaker parts—or it may be a contactor, or a master switch or any other similar device—to check the accessibility of parts, ease of repairs and so on. I may further check my opinion on any device by asking a "man who owns one." In short, regarding these constructional details, I should be free to form my own opinion which may be, broadly speaking, fully as valuable, if not more so, than the manufacturer's viewpoint.

Then, of course, I may study the whole switching and control scheme; i.e. I will analyze the Combination and Arrangement of the several apparatus. Here, quite obviously, I am fully on my own ground: I will have to run this equipment, I do or I should know what arrangement is the best and, ordinarily, I should be able to even give a few points to the manufacturer's engineers, provided that I am qualified to discuss these matters at all.

With this part of the analysis out of my way, I still have to compare the machines—motors, generators and so on—which are included in the several proposals. What standard of comparison should I select?

In my invitation for bids I have requested the manufacturers—following an old precedent if nothing else—to furnish me with detailed data on segragated weights, dimensions, efficiency, overload capacity,

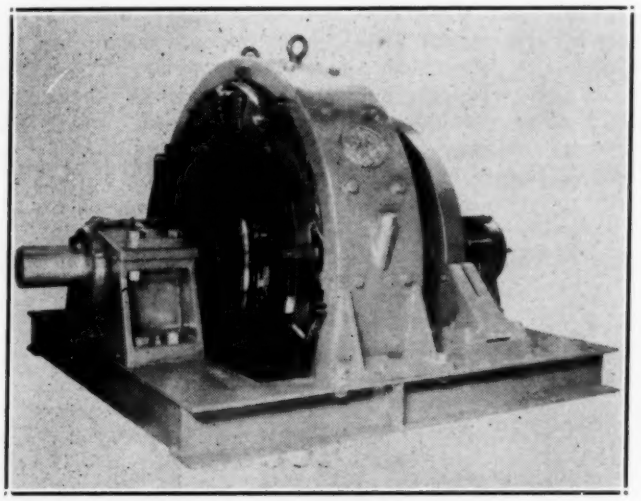


FIG. 1—1000 HP-400/800 RPM-230 Volts, D.C. Rolling mill motor, built in 1928. Magnet frame made of slabs but to circular shape; base welded of structural shapes. The use of rolled steel greatly reduces the dead weight of motor.

and so on. I may now tabulate all this information in a systematic way; this tabulation looks quite impressive; it gives me at first the feeling that at last I have a logical and unpartial method of selecting the best. With personal preferences, if any, thrown overboard, I decide to let the dry figures and cold facts be my guides.

It does not take me long to become somewhat disappointed; the more I look at these figures and the more I think of what they represent, the harder seems my job to me.

Let us take the weights to begin with. This certainly is the steel man's hobby. He measures the success of his mills in tons of product, i.e. in terms of weight; he even buys a lot of bulk machinery at so much per pound. It is quite natural—but far from reasonable—that one frequently finds a tendency to apply the same "measuring stick" in selecting electrical machinery. Of course, this method, if applied in a straight forward manner, is almost as sound as buying a watch by weight. What timepiece could then compete with the famous dollar watch?

What is, indeed, the value of weight in an electric motor?

I may just as well start the story by recalling that in large electrical machines the cost of materials is around one-half of the total shop cost. In fact, if you consider such additional factors as the overhead and the manufacturer's commercial and servic-

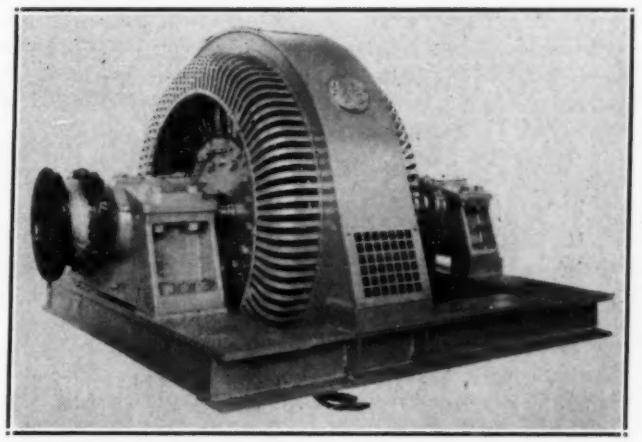


FIG. 2—Typical modern steel mill motor, fabricated of rolled steel. Rating: 1200 HP 514 RPM-2200 volts-3 phase-60 cycle synchronous motor.

ing charges, the proportion of materials in the total cost shrink to a much lower figure; well paid skilled labor; expensive machinery and other manufacturing equipment; close engineering supervision, together with thorough testing and research—all this makes up the balance.

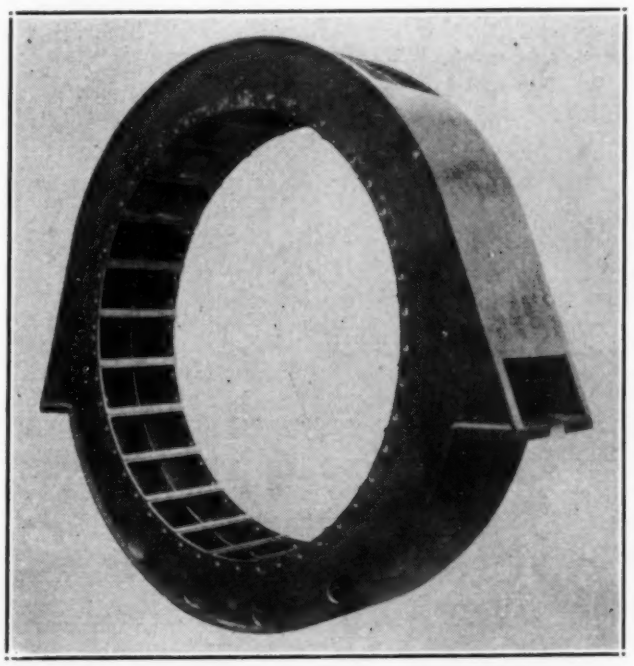


FIG. 3—Welded stator frame of a 4500 h.p-450 r.p.m. steel mill induction motor built early in 1927.

It is only arbitrarily that one can define sometimes what is "labor" and what is "material." In this case the castings are usually classed as material, although their cost includes not only the pig iron or steel but the foundry labor and overhead; likewise, the insulation, although classed as material, contains a large item of labor. If all these factors are taken into account, then the true proportion of cost of materials, used in making an electrical machine, becomes still smaller.

From the standpoint of electrical design the total amount of materials used in building a motor or a

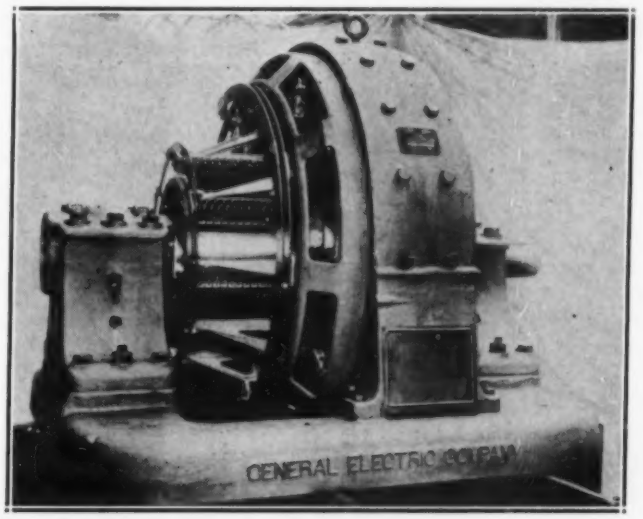


FIG. 4—750 HP-225/325 RPM-230 volts, D.C. motor built for rolling mill service some 15 years ago. Compare this construction with the one shown on Fig 2.

generator consists of two major parts; the Active material, which carries either the electric current or the magnetic flux; and the Inactive or Auxiliary material which is used to hold the first one in place or to transmit the mechanical power to or from the machine. Armature, field and commutator copper; iron punching of the armature and of the pole pieces or of the stator and rotor, as the case might be; magnet frame of d-c. machines—all these parts belong to the first class. The second class includes the

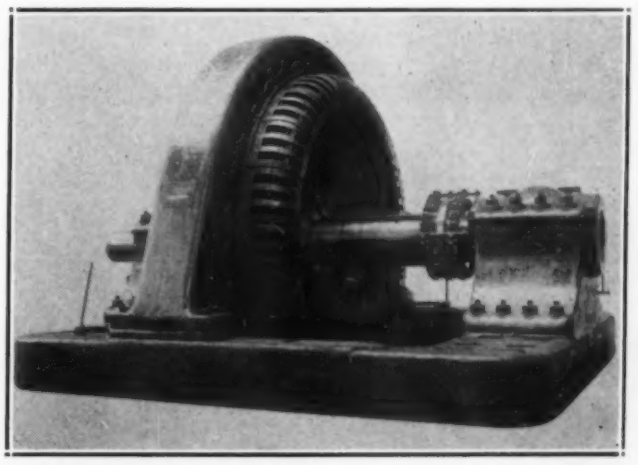


FIG. 5—3000 HP-250 RPM-6600 volt mill type induction motor built 16 years ago.

base, bearings, shaft, armature or rotor spiders, stator frames of a-c. machines and few other parts. Quite obviously, the weights of the so-called inactive parts depend to a very large extent on the distribution of the active material; this weight, taken in

itself, is far from being a measure of the mechanical strength; for instance, a designer may build a motor with a smaller diameter and a longer armature; this may increase the span between the bearings, and the shaft to remain equally rigid must have a larger

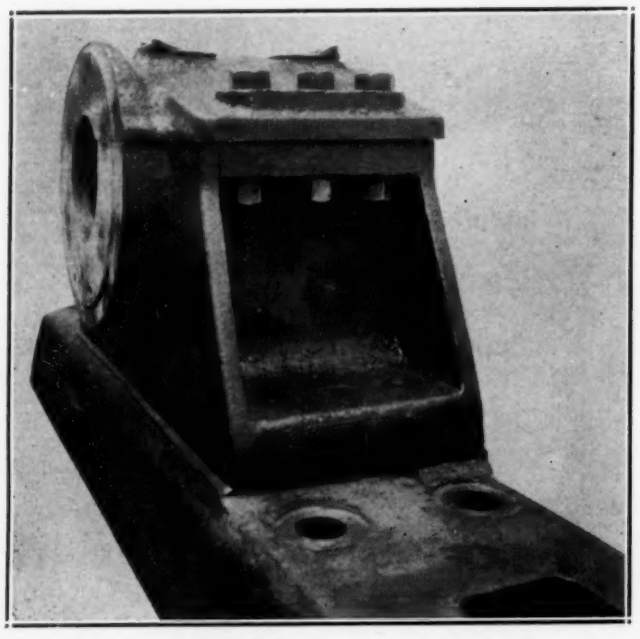


FIG. 6—Up-to-date mill type pedestal bearing which weighs much less than the old type pedestals, see Fig. 7, but is much stronger.

diameter in the armature spider besides being of necessity longer; such a shaft may weigh more than the shaft of a motor with larger diameter and shorter armature, without, at the same time, giving the purchaser any particle of extra value. This is just an illustration to show how illusory may be the application of the "weight method."

Even if I waive, for argument's sake, these incidental factors, I still may have quite serious doubts whether the weight of purely mechanical parts of the motor has necessarily a direct and proportional bearing on the mechanical strength of the machine. We will all agree, of course, that a shaft of larger diameter in the bearings is both heavier and stronger, provided the same grade of steel has been employed; but here our agreement may stop. Broadly speaking, if I assume that two or more designers, both equally conservative, produce motors of different weight, then the lighter motor, to my way of thinking, may simply mean that its designer has used better materials, or has applied them to a better advantage, i.e. in a more scientific way. A lighter motor—again everything else remaining equal—may contain less gray iron, but more gray matter. Some times greater strength and greater value are obtained with less metal and more brains.

What is, for instance, the I-beam or the H-beam, or any other structural shape produced by the steel industry, if not the engineering effort and achievement to give in each particular instance the maximum strength for a minimum weight?

Similar efforts have marked the recent years in the development of electrical machinery.

To begin with we all know, or have at least heard, of the rapid strides made in use of rolled materials in building motors and generators. Welded shapes and plates have replaced castings in making bases, stator frames, and even armature spiders. The several photographs which are here shown tell their own story.

Now, all these parts, produced by the new methods and of higher grade materials, are manifestly lighter in weight than their old fashioned counterparts. Are they their inferior in strength? Not in the least; on the contrary, when skilfully made by experienced men, they are stronger as a whole and not only stronger per pound.

Here is another illustration: Compare the two bearing designs, shown on the Figs. 6 and 7. Both may be of the same diameter, i.e. they will accommodate a shaft of the same given strength; the old bearing is massive and bulky and is, of course, quite strong. But the new bearing of late design is actually stronger, although it weighs 35% less; this is simply because the material is used where it can do most good, and the dead weight is cut out. Here again one should remember the broad idea and the underlying principle of all structural shapes.

To make this point clearer to myself I have requested a designing engineer to lay out two large steel mill induction motors of the same rating, making the electrical design of both machines identical; one motor was equipped with the up-to-date mechanical parts as just discussed, while the mechanical equipment of the other was of, say, 1922 vintage. The new style motor, complete, weighs some 15% less than the one of the old style. If the active material is left out of the picture, and only those mechanical parts are compared which were affected by the recent changes in the manufacturing practice—then the weight reduction is estimated at more than 25%.

Should the designers of this new motor offer any apologies for its lighter weight? Most certainly not; in this case they should be proud of it.

And, when these facts loom up vividly before me, my elaborate and complete tabulation begins to lose somewhat its impressiveness. I begin to doubt as to what I am going to do with all these segregated and tabulated weights after I got them.

But then I get a fresh start: let us eliminate the "inactive" parts from the comparison; let us analyze the weight of copper, of punchings and of other simi-

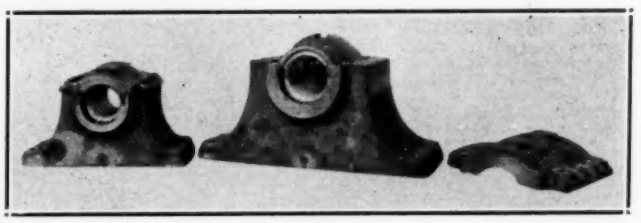


FIG. 7—Mill type pedestal bearings of the old style, superseded by the construction shown on Fig. 6.

lar parts. Certainly, I may think, copper has the same properties in either machine, the punchings also look very much alike; it seems as though the lighter are the active parts of a given motor the harder its manufacturers must have tried to work the material in it. If my imagination is sufficiently

vivid I begin to visualize the burned-out armatures, vicious sparking on the commutators and, of course, hours of delays charged to my department. And at that instant I may think: the more weight, the fuller the measure! Who will deny that this reasoning is quite often justified? Who has the right to assert, on the other hand, that this is always the case?

In the first place, let us throw overboard the idea that everything is universally known about the electrical and magnetic materials; that their properties are constant in all designs; and that no improvements are being made in, say, electric sheets. Thanks to the continuous research and thanks to the efforts of steel makers themselves—we are gradually getting better and better iron for punchings. Just the other day factory tests were made by one manufacturer on two 5000 h.p. rolling mill induction motors. Due to a new high grade iron used, their actually tested efficiency was found to be as high as 96.6% at full load and 95.3% at half-load— results not readily possible heretofore.

I have recently compared the weights of a 1929 d-c. motor, rated 500 h.p., and of a 15-year-old machine of the same rating, speed and type. The new motor weighs one-third less than the old one. It will out-perform its ancestor in every way, in spite of the lighter weight—possibly because of it. Not only were the mechanical parts modernized, but the active materials used in the new motor were better and were better used. Indeed, we should have very little patience with those who think that no motors are now as good as they were in "the good old days."

But even if I discard completely, for argument's sake, this important factor of variable quality of materials in the several designs and assume, with a self-assurance of an optimist that, after all, "pigs is pigs" and that all materials are alike—even then I may be led far astray by comparing the quality of the motors by the weight of their active parts. In laying out an electrical machine the designer uses discretion and judgment in varying the proportion of copper and active iron. He may use exactly the same electrical and magnetic densities, i.e. he may work each pound of active material equally hard in either case, and yet may build two substantially different machines—one "copper" and one "iron"—depending on whether he changes the average proportion in favor of the one or the other material. To save one pound of copper and yet get a comparable machine, several extra pounds of active iron are usually added; the machine may become heavier, but not necessarily better, nor obviously worse.

Depending on the selection of the ratio of copper to iron the total weight of active material may vary as much as 20-30%, with the electric and magnetic densities still remaining equally conservative.

The selection of the best balance between these two metals is a truly involved and a highly specialized job. Not all designers have the same idea on the subject; nor can they be expected to be equally skillful in this respect. To aggravate the matter still further one should remember that in designing a d-c. machine the problem of commutation enters quite strongly and has a decided influence on the ratio of copper and iron, i.e. on the weight of active material.

What assurance do I get, then, in analyzing my tabulation that I will pick up the best motor if I select one with the larger amount of active material? How can I introduce the undefinable factor of designing skill, knowledge and experience? In short, I may be right in, say, 50% of all cases, and may be just as easily on the wrong side of the fence in the other 50%. I may, then, just as well toss a coin!

My method of comparison, so invincible at the first glance, receives a second set back. I am beginning to realize that when we purchase electric motors or generators—we do not buy pounds of materials; we buy Performance. We may pass our judgment on efficiency, power factor, overload capacity and on any other feature which may or does affect this performance. We may stipulate, if we wish, how all these characteristics can be demonstrated by test, or how the successful operation should be backed up by a guarantee. This is always our right and is often our duty. But, quite obviously, it should be fully up to the manufacturers to select the proper amount of material to accomplish these results. Their reputation is at stake; this in itself should be enough not to let them take any chances.

And so I decide to buy "Performance." What is the primary duty of an electric machine? Quite obviously, it is the transformation of energy from one form into another, with a minimum of losses, with a maximum reliability and at a minimum cost. This sounds as an old story, and so it undeniably is.

Assuming a designer of appreciable skill, best materials to work with, and no limit on cost—machines of exceptionally high efficiencies may be produced. Even with an eye on the costs, the engineers have built such remarkable apparatus as a transformer with 99.5% efficiency, a steel mill synchronous motor with an efficiency of 97.5%, and a mill type induction motor with an efficiency of 96.6%. These are, of course, outstanding cases—but just think of what could be obtained if cost were not a factor!

But, we may ask: What price efficiency? If I were buying a generator for a power house selling power and carrying a high load factor I would be justified in paying a high premium for an extra point in efficiency. After all, my entire gross income, derived from sale of power, figuratively speaking, passes through this or like generators,

With the steel mill equipments, particularly with the main roll drives, the situation is usually quite different. If we assume that a ton of average steel mill product requires 100 KW-hours consumed by the main roll drives, then the total cost of power is usually less than $1 per ton as compared with the average market price of steel of $40 per ton. Thus, for every extra percent of motor efficiency, we would be saving on an average not more than 1 cent per ton. Even a penny is worth saving, particularly when these pennies are multiplied by millions at the end of a year. But, quite obviously, there should be less incentive on the part of the steel mills to invest heavily in improving by one or two points the apparent efficiency of their mill motor drives, than is the case with, say, a public utility. There are many other departments in the steel mills where a similar investment would bring higher returns. We, electrical engineers, should be the first ones to admit this fact when it exists. Is it not, after all, the highest compliment that may be paid to our profession?; for it is harder to improve the already

improved, and it is easier to raise the efficiency of the less efficient.

But, of course, if I have a choice of buying a more efficient machine without paying an extra high premium, and of getting at the same time a machine of a most reliable make—then I should take this opportunity. But, first of all, I must make it clear to myself, what kind of efficiency I should look for.

One of the competing machines may have a full load efficiency higher than the others; on the other hand, it may not compare as well when running at part load. Which feature is more important for me?

Only very seldom may we find a main roll drive which is loaded steadily up to its rating. It may be, for instance, a continuous rod mill, making No. 5 rods day in and day out, with practically no intervals between bars. But this is rather an exception. An up-to-date mill, with individual drives for nearly every stand cannot be expected to have each motor always fully loaded. More often than not the average load is around 50% of the installed capacity.

The capacity of each drive has been selected to roll successfully the hardest pass of any section that the mill may produce. What is the hardest section for one stand may be the easiest work for another motor or motors at the same mill, and they will then run underloaded. Then, again, my mill may be rolling for weeks at a time some other sections when all drives will be underloaded. Where does the full-load efficiency come in?

To make the picture still more complete, I must also remember that the "time-efficiency" of my mill is apt to be much below 100%. By this I mean that the successive bars do not follow each other as closely as permitted by the mill layout; the number of linear feet of product is far below the maximum possible footage.

Very likely the mill speed was selected from the standpoint of most successful rolling, which speed is considerably in excess of my tonnage requirements. The net result of all this is that the total sum of running light periods is quite appreciable, much more so than we are apt to realize. Running light losses pile up by the end of the month a very sizable amount of kilowatt hours, and greatly contribute to my monthly bill.

I have recently analyzed an operation of a medium size continuous hot strip mill, equipped with d-c. motors and synchronous motor generators. Rolling steadily on the average section for which it has been designed, the mill could have produced close to 50,000 tons per month; the power consumption would be around 65 KW-hours per ton. But actually the mill produced only 15,000 tons in 580 operating hours, and this was considered as a good record by the management; the watt-hour meter recorded approximately 1,600,000 KWH that month, which gave 107 KWH per ton. Now, this mill running empty, together with the motors and the motor generators, takes around 600 KW from the a-c. line; the "time efficiency" was around 50%. Thus, for 290 hours during that month (this is a sum of small periods, lasting few minutes or less at a time) the mill was running empty, consuming in this way a total of $600 \times 290 = 174{,}000$ KWH, or 11% of the total energy used. These are my fixed charges—my "readiness to roll" expenditure.

These facts will make you readily agree with me that for most of our mills the low running light losses are quite often fully as important as the high full load efficiency. In fact, if I paid any attention at all to the efficiencies I would be inclined to favor an equipment that would excel at part loads, even at a sacrifice of efficiency at full load.

In my desire of reducing the running light losses I am apt to run into another allied problem. I said that my mill requires a motor generator set. Shall I have the synchronous motor of this set with a .8 or 1.0 power factor ? A unity power factor set will not only have much lower running light losses, but the full load efficiency is also far better than with a .8 PF equipment. For instance, a 4000 KW motor generator set will take from the a-c. line some 40 KW less at full load, and some 25 KW less at no-load, if the synchronous motor is built for 1.0 PF instead of .8 PF.

Of course, if the power factor situation at my plant is such that it needs correction, either from the standpoint of penalty and bonus clause, or for any other reasons—then I should be glad to use this golden opportunity; I should buy a more expensive synchronous motor and charge the extra cost to the power factor clause. This is so obvious that it hardly needs any mentioning if it were not for a noticeable tendency to decide this problem by habit rather than by analysis.

By specifying, without discrimination, leading power factor motors, we are apt to lean so far that way as to make the power factor of the whole mill leading, which may be just as bad as lagging. In such a case we are selecting a machine which may cost more, has lower efficiency, and has higher running light losses. Truly, we may thus easily make a blunder almost as glaring as the one in the story which I have told in the very beginning.

At this point I will end my sketchy remarks on the selection of electrical equipment. This subject may be extended to a much greater length and may be presented by someone else in a more complete manner at some future time.

I would be greatly disappointed if all of you will agree with all of my statements. I hope to find a difference of opinions. No agreements are good unless after arguments.

And at the end I wish to add a few words which should be quite appropriate for this convention and for the topic just discussed.

Conservatism and caution are, of course, quite welcome when it comes to watching the interests of our mills and our factories. But, let not this conservatism degenerate into an old age tendency to decide the problems through the force of habit and to regard new developments as a heresy. Instead of praising the "good old days" let us rather look forward and welcome any sign of new ways and new thoughts in engineering.

Questionnaire Covering the Organization, Maintenance, Operation of an Electrical Department in a Modern Steel Mill.

By J. J. BOOTH*

Electricity in the Iron and Steel Industry in the United States had its inception in 1882 with the installation of a two-light arc dynamo driven from a line shaft in the Machine Shop of the Edgar Thomson Works of the Carnegie Steel Co., Braddock, Pa. In 1891, a 50 Hp. 250 volt, compound wound, direct current, generator and three (3) 220-volt motors were installed in the same works.

The first motors installed in the steel mills for crane and table service were modifications of standard railway motors, and it was not until 1907 that the steel mill trade were able to buy what was termed distinctive mill type direct current motors.

Along with the application of electricity for cranes, tables, etc., came the installation of large motors for the main roll drives. The first installation of this kind in the United States was also made at the Edgar Thomson Works of the Carnegie Steel Co. in 1907 by the installation of two (2) 1500 Hp. direct current motors, driving the main rolls of the light rail mill. During the year of 1907, there was installed at the South Works of the Illinois Steel Co., South Chicago, the first reversing mill motor equipment built in this country, driving the 30 in. Universal Plate Mill. Both of the above installations are still in service today giving excellent results.

From these early installations up to the present time there has been a phenomenal growth in the application of electricity in the Iron and Steel Industry, until today we have two and one-fourth million installed horsepower on main roll drives, and four and one-half to five million installed horsepower on auxiliary equipment.

During this period the electrical department has advanced from the one-man arc light trimmer to one of the largest departments in the organization of any modern, up-to-date Iron and Steel Plant. At the same time electricity has made such strides in the Iron and Steel Industry, our Association has made equally rapid strides.

The Association of Iron and Steel Electrical Engineers was organized in April, 1907, with a group of about twenty engineers, and today we have a membership of about 2,000 with headquarters in Pittsburgh, Pa., and branch sections in Philadelphia, Cleveland, Birmingham and Chicago.

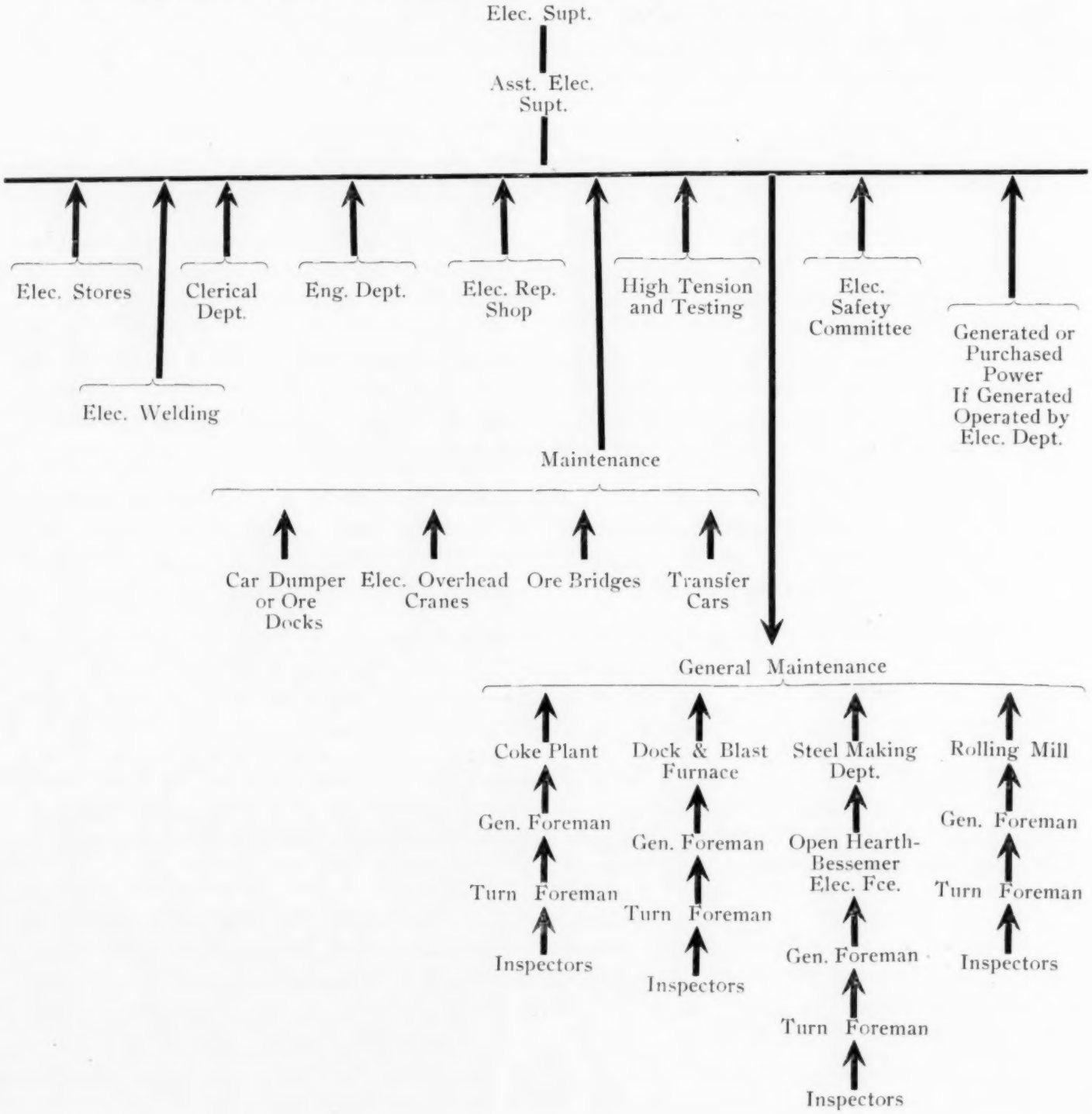
From the above outstanding statements, you can readily see that electricity has made great advancements in the Iron and Steel Industry, and the questionnaire which is printed herewith will assist your executive officers to compile and print information and data which will be helpful to any steel mill electrical man, be he situated in a small or large plant.

*Chairman Shop Practice Committee A. I. & S. E. E., Elec. Engr., National Tube Co., Gary, Ind.

The officers of your Association will appreciate any help and co-operation which you may lend in the form of data, charts, curves, cost figures, etc., which will assist in the compilation of this work.

ORGANIZATION

1. Give general layout of organization using tree below as guide.



2. State size of plant.
   a. Number of employees.
   b. What comprises plant—Blast Furnace, Steel Making, Rolling Mill, etc?
   c. Finished product.
   d. Does process take from ore pile to finished product or what is layout.

A. Clerical Department—
   1. 1. Writing of orders—specifications, etc.
   2. Distribution of time—transmitting same to chief time department.
   3. Tabulation and record of test data.
   4. Tabulation and record of shop costs—if same are kept.

B. Stores—
   1. Is the electrical store under the electrical superintendent?
   2. If store comes under the chief store keeper—is there a trained electrical man in charge?
   3. Have you a maximum and minimum of ordering—regular 30-day commodities, same to be governed by consumption?
   4. Is there a close efficient check kept on store at all times so that the inventories may be a minimum consistent with efficient handling of spares, commodities, etc., or at the end of the year do you have a clean up—scrap program?
   5. What kind of card system do you run on electrical stores, submit sample store cards.
   6. Spares—To what extent do you keep spares, such as motors, armatures, etc.?

C. Engineering Department—
   1. Do you have an engineering department?
   2. If so give organization?
   3. To what extent do you go into the general engineering design of sub-stations, power houses, transmission systems, auxiliary control, crane designs, writing of specifications, etc.?
   4. Does electrical department—engineering division tie in with chief engineering department?

D. Electrical Repair Shop—
   1. General organization.
      a. Bench hands—how many?
      b. Tool room—is same under care of competent tool room man?
      c. How do you issue tools to employees, check system, card system or what not?
   2. Do you repair and rewind motors, etc., in general both AC and DC?
   3. Do you farm out any repair work to small repair shops or large service shops such as Westinghouse and General Electric?
   4. Do you have a coil winding department?
      a. Do you rewind field coils, lifting magnet coils, brake coils, small auxiliary contactor coils, etc.?
      b. Do you make your armature coils either in part or for all of your requirements?
      c. Do you have baking ovens, both large and small, or do you use air drying varnish?
      d. Do you have an impregnating outfit? If so do you impregnate coils as large as lifting magnet coils or do you confine your work to smaller coils such as armature and field coils for auxiliary motors?
   5. Does electrical shop department do any mechanical work such as cutting gears for cranes, turning shafts, machining of bearing castings, etc.?

6. If no mechanical work is done by electrical department shops how do you route your work through machine shops to get service? Do you use a card system? Real service is sometimes hard to get. Have you a checker or follow up man?
7. Do you keep a record of the causes of trouble such as armature coils shorted, grounded wiring, grounded commutator, grounded field coil, bearing trouble, etc., and having such a record try to analyze the cause and correct the trouble?
8. Have you any conclusive data concerning experience with sleeve bearings versus anti-friction bearings?
9. Do you endeavor to keep accurate costs of electrical repairs? If so submit sample card—method, etc.?
10. Is electric shop large enough to justify scheduling by time cards, etc.?
11. Do you have an inspector who checks all equipment before leaving shop?

E. Electric Overhead Traveling Cranes—Ore Bridges—Transfer Cars—Car Dumpers—Ore Unloader, etc.
1. Do the cranes come under the electrical superintendent?
2. Do Ore Bridges, Transfer Cars, Car Dumpers, Ore Unloaders, etc., come under electrical superintendent?
3. Does Electrical Superintendent handle all millwrights?
4. Does Electrical Superintendent order all repair parts, castings, gears, etc.?
5. Do the Crane Operators come under the Electrical Superintendent?
   a. If they do, give your idea of advantages.
   b. If they do not, give you idea of advantages.
6. What constitutes necessary crane equipment such as hand line, fire extinguishers, danger sign, etc., safety inspection?
7. Where do you draw the line between manual control and full magnetic control, both with respect to application and motor size?

F. High Hension Work and Testing—
1. Do you maintain a gang or department especially for handling high tension work?
2. Are your high tension lines overhead or underground? Which preferable and why?
3. Do you have a straight line system or a loop system?
4. Do you maintain a Testing Department, if so do you make a systematic test in the respective departments or random tests?
5. Does your testing equipment consist of a portable indicating and portable graphic meters, either or both. Also AC and DC standard meters for Testing Watt Hour Meters?
6. How extensive is your plant metered on individual circuits?
7. How elaborate is your power distribution report charging current to the individual users?

G. Power—
1. Is your power generated, purchased or both?
2. Do you use 25 cycle or 60 cycle and reason for same?
3. If generated what type of prime movers, steam engine, steam turbine, gas engine, one or all types, also give capacity?
4. What percentage generated from waste gases and whether fired under boilers or used in gas engines?
5. What is your generated voltage?
6. Do you use MG sets or rotaries for transformation to low tension DC?
7. Have you a rectifier in service at your plant?
8. To what extent have you gone to automatic control in sub-stations, power houses, etc.?

H. General Maintenance—
   1. How many general maintenance departments do you have?
   2. Do you carry a complete line of spares in each department?
   3. As a general rule are the Electrical Department Men on a bonus, same as producing men?
   4. Do you have foreman, on duty 24 hours a day, 7 days a week in the respective departments?
   5. If available, submit forms for daily reports, etc.?

I. Electrical Department Safety Committee—
   1. Do you have such a committee?
   2. How often do they meet?
   3. Who are eligible?
   4. How do you get your programs across to men in ranks?
   5. Do you have a complete set of safety rules—covering all departments, also special rules such as "Crane Operators," "High Tension Switching," "Rules for Foreman," etc.? If convenient, submit such rules?

J. Electric Welding—
   1. Is the Electric Welding under Electrical Superintendent?
   2. If not, is the department large enough to be under separate Superintendent?
   3. If under separate department, do you do Electric, Gas and Thermit Welding?
   4. Can you give any substantial figures covering general saving from Welding? Particularly along line of reclaiming and maintenance work?
   5. Types of machines used?
   6. Grades of Welding Electrodes?

The Combustion of Liquid Fuel

By ROBERT C. VROOM*

To completely discuss the combustion of liquid fuel beginning with the period when early man used it as a source of light and heat, would require far more time than can be devoted to the subject in this meeting. Furthermore, while historical details are of great interest to the designer and builder of equipment, the user of such apparatus is more interested in present types and in the trend of the developments in design at the present moment which indicate the possibilities for the future.

The combustion of liquid fuel takes place in two major fields. The first of these covers the use of the fuel for firing furnaces of various kinds. The second covers the combustion of fuel in internal combustion engines. In this paper there will be considered those applications which fall in the first field with particular reference to the use of liquid fuel for firing steam boilers.

Availability of Fuel Supply

A discussion of equipment for burning liquid fuel is of little value unless the availability of such fuel is assured. There seems to be no foundation in fact for the prophesy that our liquid fuel supply soon will be exhausted.

We still have great liquid oil reserves in the earth and the possibility of producing oil by improved methods from fields which have long since been abandoned. The shale oil deposits have not been touched and experimental plants for producing oil from this material have reached a point where they can be put in commercial operation when it becomes economically possible to compete with the fuel obtained from liquid deposits in the earth.

Colloidal fuel in which oil is mixed with various quantities of pulverized coal without destroying the fluidity of the mixture offers a means of extending our liquid oil reserves. Certain treatment is necessary to prevent the coal particles from settling out in the equipment and lines, and if the fuel is treated properly, it is claimed that the mixture is very stable under varying temperature conditions and that mixtures containing 50% of coal dust by weight are practicable. Also, there is the possibility of producing liquid fuels from our vast coal reserves by synthetic means. There seems to be no question but that there will be available for many years to come an adequate supply of liquid fuel. However, even with a large supply of fuel oil available, it is

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our economic and patriotic duty to see that it is consumed in the most efficient and economical manner.

Development of Burners

Some of the modern liquid fuel burners accomplish this result in a most satisfactory manner and I believe it will not be out of order to trace briefly the development of these. Centuries ago when oil was first discovered to be combustible, it was used as a source of light and heat and burned in pots or trays which were sometimes fitted with wicks. With these methods, of course, only low rates of combustion could be obtained and the fuel was burned most inefficiently.

Probably the largest step in advance occurred when it was realized that in order to burn fuel of this character, rapidly and efficiently, it should be burned in suspension in atomized form. Most of the early atomizers used an outside agent such as steam or air and atomization was accomplished by impinging the air or steam in various manners on the supply of fuel. The next development was the mechanical atomizer in which the oil was caused to rotate rapidly and the centrifugal force thus produced broke it up into a fine mist or spray when it was liberated from the outlet orifice of the atomizer.

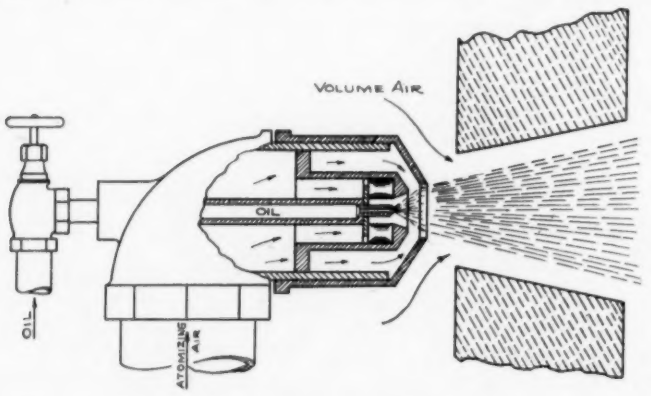


FIG. 1—Air Atomizing Oil Burner

One of the pioneers in burning oil in this country was E. H. Peabody who developed the "rear-shot" steam atomizer for use in water tube boilers and who has been so influential in developing the mechanical atomizer to its present state of perfection. His paper "Oil Fuel" presented at the International Engineering Congress at San Francisco in 1915 was and is well worth reading by one interested in this subject.

Present Types

The types of burners which are in use today for firing furnaces of various kinds are the air, steam and mechanical atomizing burners, although there are certain burners being used for household heating which still retain many of the features of the ancient pan and wick design.

Air Atomizers

A typical air atomizing burner is shown in Fig. 1. It will be noted that the atomizing air which is supplied to the burner under pressure impinges on the fuel stream (which may be supplied by gravity or pump) and breaks it up into a spray. The remainder of air necessary for combustion which is commonly known as the "volume" air is induced through the opening by which the atomized fuel enters the furnace.

There are many kinds of air atomizers, but the one illustrated is typical. Such burners find their main use in metal heat treating furnaces and in other small industrial furnaces. The atomizing air, depending on the design of the burner, is supplied at pressures ranging from a few ounces to 20 lbs. Burners of this type are at times built for capacities up to several hundred pounds of fuel per hour but probably the greatest number in use are built for considerably lower capacities.

Part of the total air required for combustion is used as atomizing air and the remainder is drawn in as "volume" air. All of these burners require an outside agent, such as a blower, or compressor to supply the atomizing air and for the capacities at which a modern power plant is operated, the operating cost of the auxiliary atomizing equipment would be prohibitive.

Steam Atomizers

Steam atomizing burners, as far as the method of atomizing is concerned, may be divided into two classes. In the outside mixing type, the fuel and the atomizing steam impinge on each other immediately upon leaving the burner through their respective nozzles as shown in Fig. 2. In the inside mixing type, the atomizing steam and air impinge on each other within the burner body, the fuel being vaporized to a certain extent and it is this vaporized mixture which enters the furnace. (See Fig. 3.) Steam atomizing burners may have their outlet nozzles designed so as to produce flames of various shapes. The design must be such that the capacity is not limited by the steam blocking off the flow of oil.

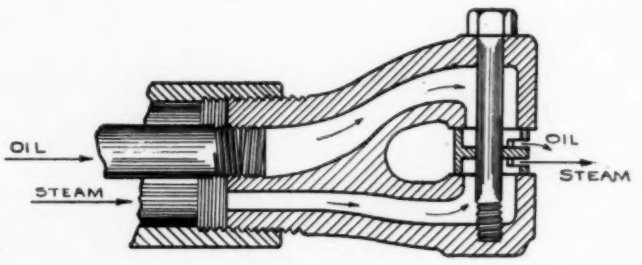


FIG. 2—Outside Mixing Steam Atomizer Flat Flame Type

For many years the flat flame steam atomizer was most commonly employed. This type of burner produces a spray in the shape of a "fish tail," the plane of the spray usually being horizontal. The air for combustion is induced at low velocity by the furnace draft through a checkerwork brick floor immediately under the sheet of atomized oil. It is obvious that with this type of air admission, the mixture of the air with the fuel is slow, the air having ready access to only the lower side of the atomized sheet and burners of this type may be termed "long burning."

Fig. 4 shows an installation of this type. It will be noted that the furnace is of the "rear-shot" type, local flame inpingement being largely avoided by this method of taking advantage of the expanding furnace volume.

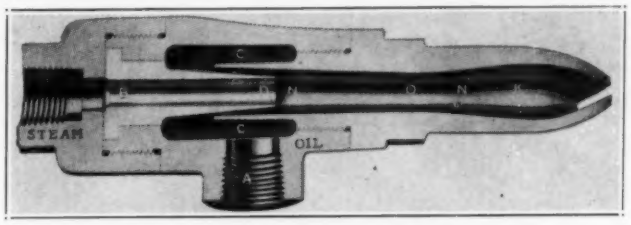


FIG. 3—Inside Mixing Steam Atomizer

In an endeavor to produce a more efficient mixing of the fuel with the air, and to enable a greater number of burners to be installed, in any one furnace, a steam atomizing burner having a conical spray has been introduced through the center of an air register of the type ordinarily used with the mechanical atomizer. By admitting the air with a rotary motion through the curved shutters of this air register, it can be inpinged on the fuel spray at high velocity and a more rapid and efficient mixture can be produced.

Burners of the steam atomizing type are built for capacities of from 25 lbs. per hour up to capacities of 2,000 lbs. or more per hour. Depending upon the capacity and the design, the oil pressure may range from 15 to 50 lbs. or more. Steam pressures from 10 to 100 lbs. are employed in various designs.

In order to obtain proper atomization, it is necessary to preheat the heavier grades of fuel oil to reduce their viscosity. With most steam atomizing burners it is satisfactory to preheat the oil to a temperature which will give a viscosity of approximately 300 seconds Saybolt Universal.

While steam can be a very effective atomizing agent, it is not necessarily an economical one. As

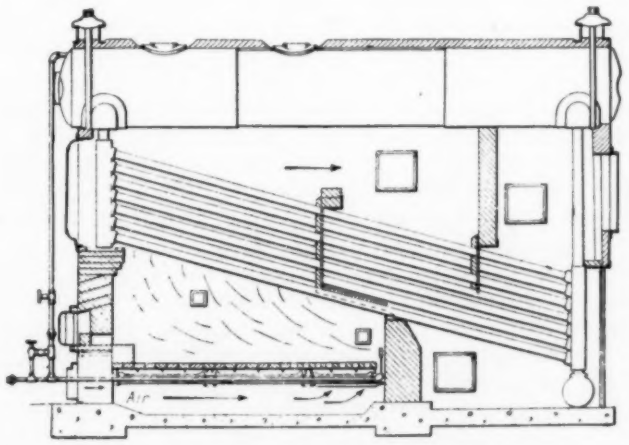


FIG. 4—Peabody Rear-Shot Furnace

a matter of fact, flameless combustion can be obtained with a steam atomizing burner, but if we assume the burners to be used for boiler firing, as much as 15 per cent of the total steam produced may be required as atomizing steam to obtain this condition. The steam must be heated to the temperature of the exit gases leaving the boiler and it is absolutely lost, there being no way to recover its latent heat.

In a boiler plant, under test conditions and with the very best supervision, the quantity of steam re-

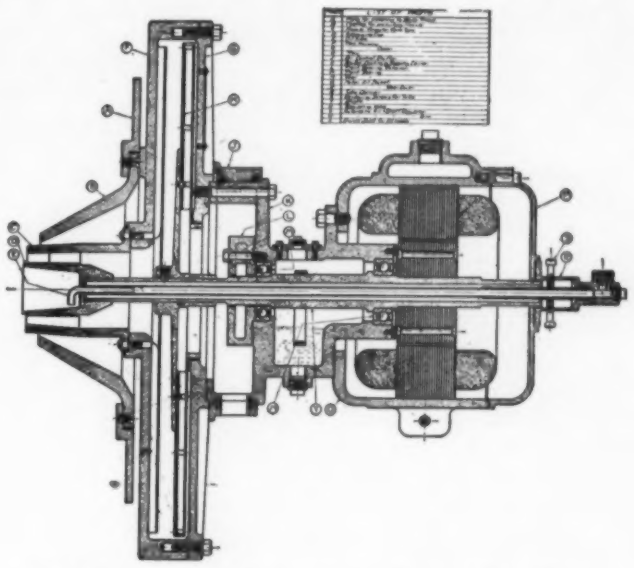


FIG. 5—Mechanical Atomizer—Rotary Cup Type

quired for atomizing will hardly be less than 2 per cent of the total steam produced. Three to four per cent. is a common figure in ordinary plants and a careless fireman may easily run this up to 8 or 10 per cent. A considerable amount of steam is required for atomizing with any steam atomizer whether it is a round flame burner in an air register or a flat flame burner over a checkerwork and it was this fact that led to the development of the mechanical atomizer for marine purposes, because on board ship it is not practicable to waste up the stack the fresh water which is required for the atomizing steam.

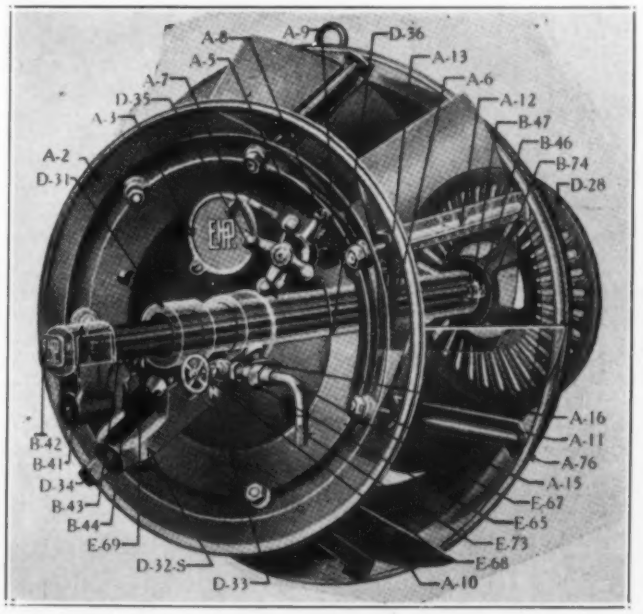


FIG. 6—Wide Range Mechanical Atomizer and Air Register

Mechanical Atomizers—Rotary Cup Type.

Mechanical atomization is by no means new. In 1868 a patent was granted to one Frederick Cook, the claims covering "the introduction and distribution by centrifugal force of liquid hydrd-carbon into furnaces as fuel." Cook employed a hollow shaft which was rotated at high speed. Oil was fed through this shaft into a cup attached to its end and was thrown out by centrifugal force in the form of a spray. This method has been used to some extent for power purposes in recent years, but it has been used to a greater extent for domestic application.

In the burners of this class ordinarily found in household heating or small industrial installations, the rotation of the cup is often produced by an air turbine which is driven by part of the air supplied under pressure for the combustion of the fuel. The more common method of rotating the cup is to have it attached to the shaft of a motor or turbine. In this latter type, there is generally a fan mounted on the same shaft as the cup and this supplies the air necessary for combustion. (See Fig. 5). It is said that burners have been built for capacities up to 1500 lbs. of oil per hour and that even heavy grades of fuel may be fed to the burner under gravity and without being preheated. The cup speed of such burners is from 1800 to 3500 revolutions per minute, and they thus require the same attention as any other piece of high speed machinery. Also, each burner being an entirely separate unit, it may be a bit difficult to regulate all burners in a furnace so that each is delivering the same amount of fuel and air.

In discussing such burners the power consumed in driving the fan and the rotating cup must be considered. The catalogue of a manufacturer of one well-known type of rotary atomizer states that for a burner having a maximum capacity of 200 gallons or approximately 1600 lbs. of oil per hour, there is required a 7½ HP driving motor, and for one of 60 gallons per hour (approximately 500 lbs.) a 2 HP motor. From this it can be seen that the auxiliary power required to operate one of these burners is not an inconsiderable item.

Mechanical Atomizers—Pressure Type.

The pressure type of mechanical atomizer which has been used so extensively produces a spray through centrifugal force by permitting oil under pressure to gain velocity in passing through slots substantially tangent to a conical chamber, and then allowing this rotating oil to escape through an orifice on the axis and at the apex of this chamber.

Oil Pressure.

The ordinary inlet oil pressure for mechanical atomizers of the pressure type is 200 lbs. per sq. in. although they may be operated at a pressure of 50 lbs.

Viscosity Regulation.

The temperature at which the oil must be delivered to the burner depends entirely upon the viscosity. The temperature should be so regulated that the viscosity will be reduced to approximately 180 seconds Saybolt Universal, which will make the oil sufficiently fluid to break up into a fine mist due to the centrifugal action.

In order to determine the proper temperature, a laboratory test of the oil must be made. There has recently been developed a device for regulating viscosity by viscosity so that as the grade of oil being used varies, the steam to the heaters is automatically regulated without any test being required.

"Blower" Burners.

One development which for a time gained considerable prominence had the atomizer insterted through the hollow shaft of a turbine driving a blower for discharging air under pressure around the conical spray. This has been called the "blower" burner. It originated in the U. S. Navy and was found very effective in saving fuel on destroyers while in port. Under these conditions, the load is light and by the use of a few of these units having the integral fan to overcome the draft loss of the air through the burners, the large fans used for forcing the air into the closed fire room while at sea could be shut down. The prophecy that the burner would displace the usual air register type proved very short-lived.

"Air Register" Burners.

The "air register" mechanical pressure atomizer produces a spray in the same fashion but the air for combustion is given a rotary motion in passing through an air register preferably fitted with curved blades. (See Fig. 6). This rapidly rotating column of air impinges on the conical oil spray which of itself does not rotate and picks up this spray to produce a flame having a marked "corkscrew" action which greatly promotes turbulence and assures rapid and complete combustion. It is this principle (long successfully used in oil burning) which is now being applied so effectively in burning pulverized coal in small combustion chambers. It will be noted that this burner has movable but no moving parts.

By this method, any number of burners may be fitted to a single furnace and operated at the same capacity, each being supplied from a common oil header. The air for combustion which passes through the air register may be admitted by natural or forced draft. If natural (or induced) draft be used, sufficient draft must be produced in the furnace to overcome the draft loss through the air register, with the result that the furnace pressure is always negative to the atmosphere by a considerable amount. If forced draft be used, the air registers may be fitted in a common windbox or plenum chamber, the forced draft blower supplying the air at a maximum of a few inches of water column to overcome the draft loss through the air register and the furnace draft being maintained at approximately a balanced condition, i. e. .1" of water column or less under the atmospheric pressure.

It is such forced draft installations which are being employed so successfully in firing high capacity boilers in modern public utility plants where efficiency, economy and continuity of operation are of such prime importance. (See Fig. 11-12-13).

Maximum Capacity.

In such plants it is quite common to find mechanical atomizers handling 1500 lbs. per hour and there are in **commercial** operation many burners having a capacity of over 1800 lbs. per hour. There appears to be no definite limit to the individual burner capacity possible, assuming that there is no material increase in heat liberation in the furnace and provided the necessary draft conditions are available. This is no difficulty at all in designing a mechanical atomizer to spray a very much greater quantity of oil than is now commonly employed in commercial practice.

Limitations of Ordinary Mechanical Atomizers.

The ordinary mechanical atomizer, however, has a very distinct limitation in that with any given atomizer, the obtainable capacity range is very narrow. Let us assume an initial oil pressure of 200 lbs. per sq. in. gauge which is an ordinary operating pressure as being that required to give the maximum burner capacity. If it is desired to decrease the capacity without having some burners in a furnace unlighted, or without changing the size of burner tips in all burners, it is necessary to reduce this initial pressure.

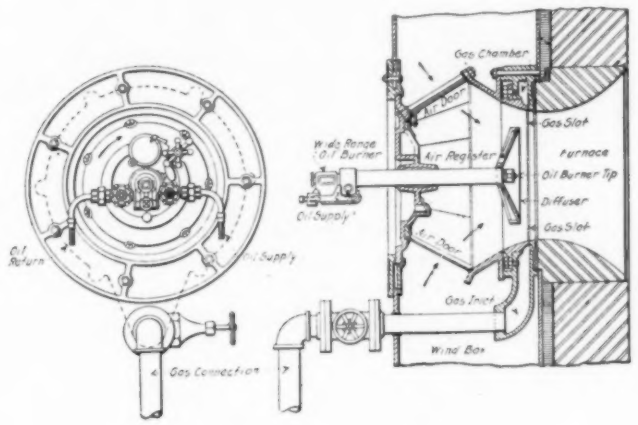


FIG. 7—Combined Gas and Oil Burner

As the ability to atomize oil successfully depends on the whirling action produced (which in turn depends upon the velocity through the tangential slots) it is obvious that any reduction in supply pressure will decrease this velocity and cause the atomization to be less satisfactory with resultant delay in speed of combustion. Ordinarily, it is assumed that about 50 lbs. is the minimum pressure at which satisfactory atomization can be obtained although there are some burners which are claimed to operate satisfactorily at lower pressures. However, if we assume 50 lbs. as the minimum practicable pressure, this means that in dropping the pressure from 200 lbs. to 50 lbs., the capacity of the burner has been decreased from its maximum to about 50% of the maximum which represents a load range of 2 to 1. This is entirely insufficient for ordinary operation. It will be noted that a burner using a maximum pressure of 100 lbs. has on this basis a minimum capacity which is only about 70% of the maximum.

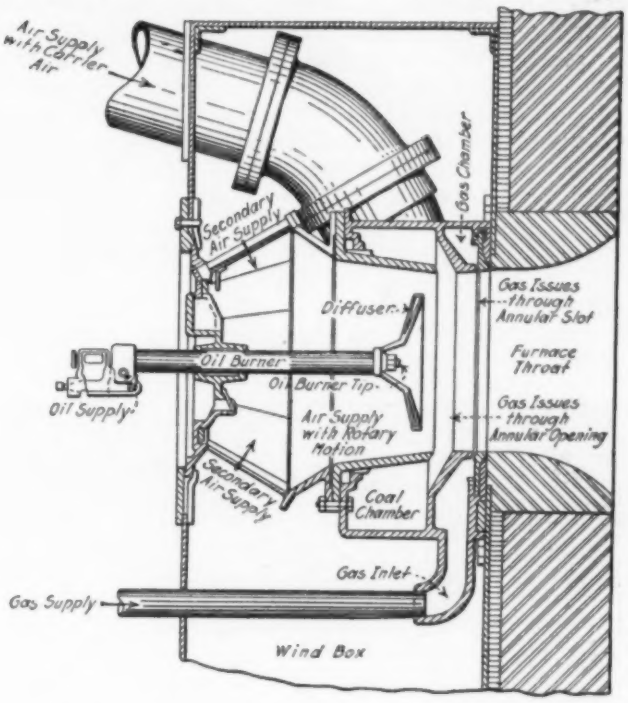
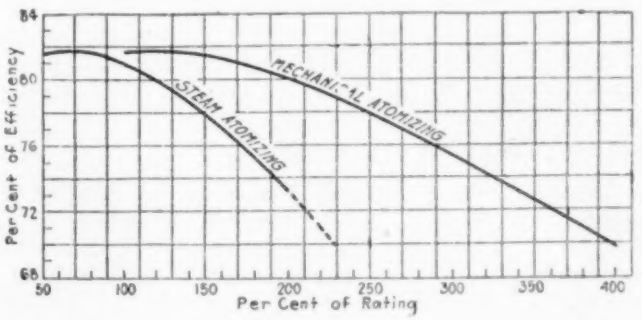


FIG. 8—Three-Fuel Burner—Oil, Gas, Pulverized Coal

Wide Range Burners.

In order to overcome this difficulty, several ingenuous types of burners were produced. Most of these were adjustable individually by throttling the inlet slots in some way and although the tangential velocity could be maintained in this fashion, the individual adjustment was objectionable from the standpoint of labor, and it also meant that it was very easy to have one of several burners firing a given furnace operating at a different capacity from the others. Another device in effect consisted of two atomizers in a given burner, each having its own oil supply line. This type, however, had the disadvantage of not being a true wide range burner but a "high-low" burner, i. e., it had a definite maximum and minimum capacity and could only partially meet any intervening load conditions by changing the inlet oil pressure.

These methods of obtaining wide capacity range were only partially effective and the Peabody Fisher Mechanical Burner introduced in 1920 was designed to give a wide capacity range with centralized control. This burner obtains this result by returning



COMPARISON OF STEAM AND MECHANICAL BURNERS

FIG. 9—Comparison of Steam and Mechanical Burners

a certain portion of the oil supplied after it has passed through the tangential slots in the burner tip and has received its whirling motion. In this way, there is always a constant quantity of oil passing through the slots of the burner with the result that the centrifugal action and the atomization is not destroyed at the lower capacities. The slots and orifice of the atomizer are located in one piece called the "tip."

This method of control makes it possible to operate the burner from any predetermined maximum burner capacity to a minimum capacity of approximately 15% of this and it is possible to operate the burner without reduced efficiency at

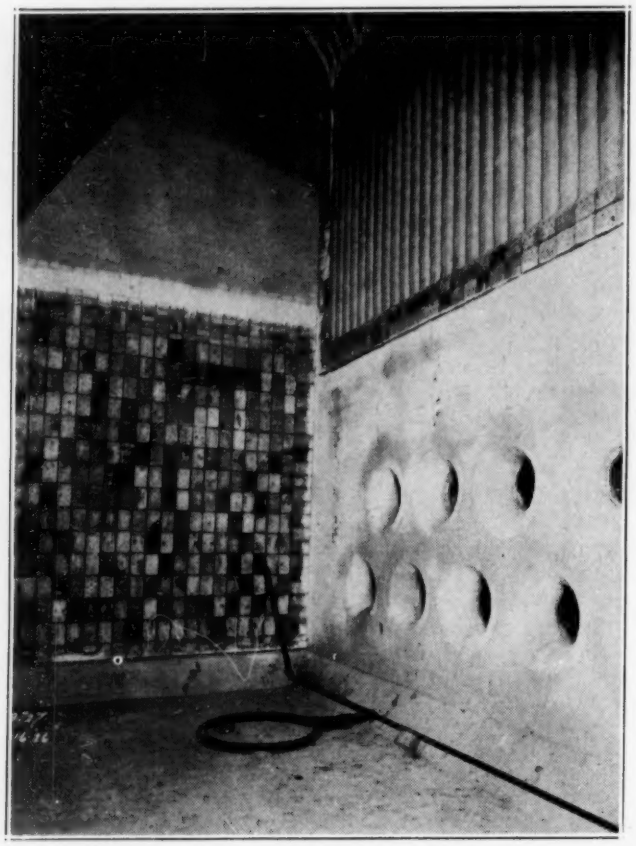


FIG. 10

any capacity between the maximum and the minimum. As will be noted, this is a very marked increase in the usual capacity range obtainable with the ordinary mechanical burner without changing tips or leaving certain burners in a furnace unlighted. Also any number of burners may have their individual returns connected into a common header and the capacity of all may be varied alike by the operation of a single control valve in this header.

Combined Burners.

Another advantage of this type of burner is that it can be used in combined units for firing oil gas or pulverized fuel. Plate No. 7 shows a combined oil and gas burner which has been extensively used for firing fuel oil and natural gas and the liquid and gaseous residues from oil cracking stills. It will be evident that the gas burner proper consists essentially of a gas chamber of annular form into which the gas is delivered under pressure. The outlet from this chamber is in the form of a circular aperture or slots which surrounds the furnace throat, the gas being discharged in a thin film of conical form, the apex of the cone being concentric with the center of the throat opening. The air register is the same as that used when burning oil only, and is attached to the gas chamber in such a way that the air is delivered to the throat opening with a rapidly whirling motion.

Fig. 8 illustrates a burner for handling any one of three fuels: oil, gas or pulverized coal. The method of admission for the coal is similar to that used for gas alone except that the coal section of

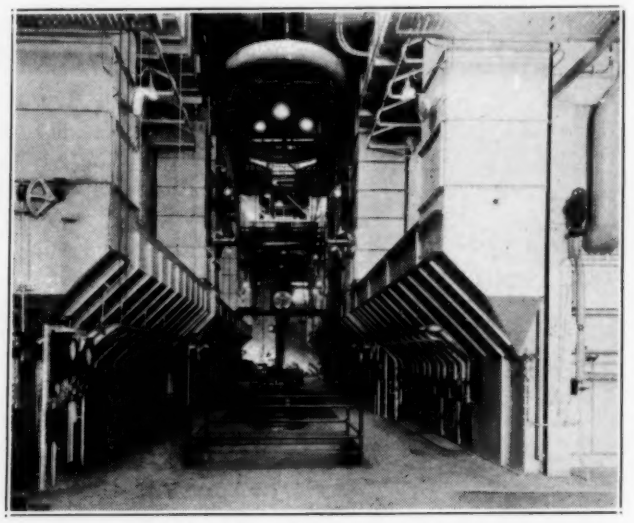


FIG. 11.

the chamber surrounding the furnace throat, is made in the shape of a scroll or involute and the pulverized coal with a certain amount of carrier air is admitted through an inlet tangent to this casing. This shape insures a uniform velocity of the fuel and carrier air as it passes around the chamber. The coal issues into the throat through a circumferential slot or aperture behind the gas slot. An example of the rapid and complete combustion produced by this type of burner designed to burn coal and oil is shown by the fact that it made possible the use of pulverized coal in Scotch marine boilers and resulted in the successful installation on board the U. S. Shipping Board S. S. MERCER which has made many voyages between Rotterdam and New York (see Fig. 14).

Types of Fuel.

One of the things which can be accomplished with the Peabody Fisher Burner due to its wide range capacity feature is that in it there can be burned liquids not ordinarily considered as commercial fuels. Dubbs residuum, the liquid residue from Dubbs oil cracking stills has been successfully burned in a mechanical atomizer by making use of this wide range feature. This fluid is very heavy and contains about 30 per cent of base settlings and water and a great quantity of lamp black carried in **unstable** suspension in the liquid fuel. This lamp black will actually settle out of the fuel unless it is kept in circulation in the storage tank.

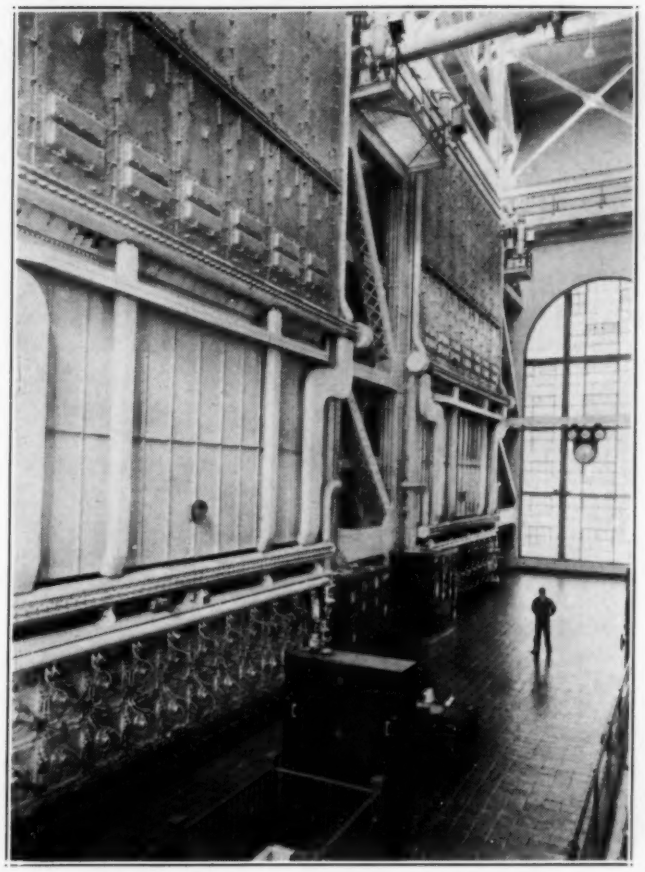


FIG. 12.

Burners of this type have been in operation for some time with this fuel and the results have been eminently satisfactory.

Comparison of Burners.

The burners just described comprise the major types in use today and it may be of some interest to make a brief comparison between these types. It is obvious that a single type of burner cannot be used successfully in every type of furnace although it is a fact that in the many different types and shapes of modern boiler furnaces the mechanical atomizer of the pressure type has become the standard equipment.

For certain industrial applications, the low quantity of oil per burner or the shape of the furnace may make the mechanical atomizer unsuitable. In such cases, the air or steam atomizer finds its greatest application. However, the question of whether air or steam should be used is one that has to be decided on the merits for every particular installation. The availability of the atomizinz agent, the cost of auxiliary power and the atmosphere desired in the furnace are all questions which must be considered. Air atomizing burners, if operating at relatively high capacities (for this type) will require a compressor instead of a blower for delivering the atomizing air. While the operating charges for running the compressor may not exceed those fo rsupplying atomizing steam, still if the latter is available, the installation as a whole becomes less complicated.

For many years after the discovery of fuel oil in this country, the steam atomizer was used extensively for gring steam boilers. However, the advent of the mechanical atomizer and its development to its present state has led to its adoption for modern boiler plants operating at high rates of evaporation per unit of boiler heating surface. The mechanical atomizer is relatively quiet compared with the stea matomizing burner and in case economizers are used, there is no atomizing steam to increase the percentage of moisture in the flue gases and consequently the tendency for these gases to reach the dew point and deposit moisture on the economizer tubes.

Also, the use of the mechanical atomizer has enabled the heat liberation per cubic foot of furnace volume to be increased materially without added maintenance of the brick work. Then, too, in the steam atomizer of the flat flame type, the air is admitted to the bottom of the flame at low velocity through a checkerwork in the floor. In this way, only one half of the surface of the atomized oil is exposed to the air. Flat flame burners cannot be place in a double row across the front of the boiler, and the number in a single row is limited by the fact that the flame from adjacent burners should not impinge. If an endeavor is made to increase the heat liberation in the furnace by increasing the capacity of the individual burners and in this way increasing the thickness of the atomized sheet of oil, difficulty will be found in obtaining satisfactory mixture with the combustion air.

Steam atomizers are often used where first cost is considered more important than the increased operating cost due to the use of excessive quantities of atomizing steam. Not only is the net efficiency with steam atomizing burners lower than that with mechanical atomizers, due to the charges for atomizing steam but also the gross efficiency is lower, particularly at the higher boiler ratings. An illustration of this fact is shown by the reprint of the curves of Jacobus and Lewis published in the 1921 Prime Movers report of the National Electric Light Association (Fig. 9). These curves show boiler efficiency data based on tests made by eminent en-

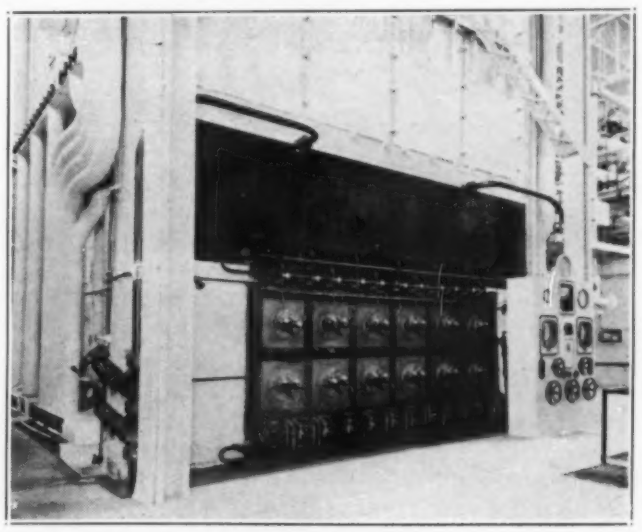


FIG. 13.

gineers and are therefore more dependable than theoretical figures.

Flame Impingement.

Another point which bears upon the type of burner to be selected is the question of flame impingement. The following paragraphs are quoted from a paper entitled "The Burning of Liquid Fuel" delivered by Ernest H. Peabody at the First National Meeting of the A. S. M. E., Fuels Division, in St. Louis in 1927. Mr. Peabody says: "Local flame impingement, that is impingement on one spot of small area, may cause overheating of the metal forming the heating surface of any type of boiler, even when the water side oi the metal is free from scale. On the other hand, at least in the case of water tubes having an inclination of 15 degrees with the horizontal, if the flame is distributed along a space of 1½ or 2 feet, the water circulation will re-establish itself and keep the metal cool. This fact was repeatedly demonstrated in the experiments leading up to the development of the rear-shot burner, already referred to.

This statement does not hold if the metal on the water side is coated with oil or scale, and it may be noted here that the most dangerous form of scale is loose scale which may pile up in one place in the tube, one layer over the other, and thus effectively prevent water from reaching the tube surface as soon as the boiler begins to make steam. This loose scale is likely to be washed out of the tube when the boiler is emptied, and then there will be the mysterious condition, which the plant engineer finds hard to explain, of an apparently perfectly clean tube having been burned by a well distributed flame. Of course, even loose scale may exist in a tube without doing any damage if the boiler is not forced—it all depends on how fast the water is evaporated

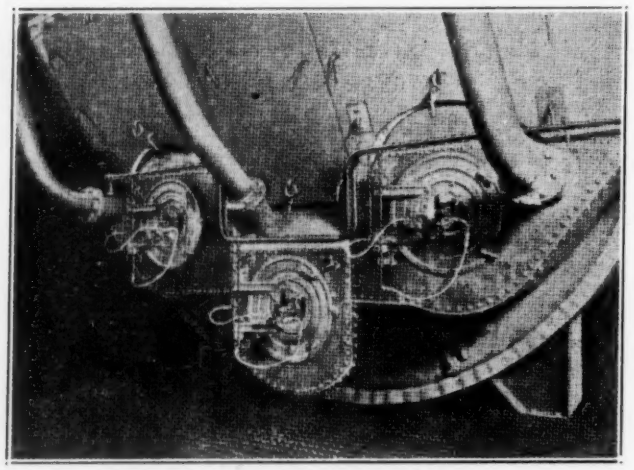


FIG. 14—Pulverized-Coal and Oil Burners for Scotch Boilers

and how dense the pile of scale may be—but when scale is present an attempt to operate the boiler above rated capacity will almost certainly cause trouble. The author knows of cases where the flame has extended well into the second pass of a clean boiler with no trouble resulting. This, of course, implies flame impingement, but a distributed flame.

The steam atomizer may produce "blowpipe" action; a mechanical burner, properly operated, never will. The steam jet of the former gives the flame high velocity and a concentrated character while the latter is soft and well diffused. This explains why the "rear-shot" method was necessary with

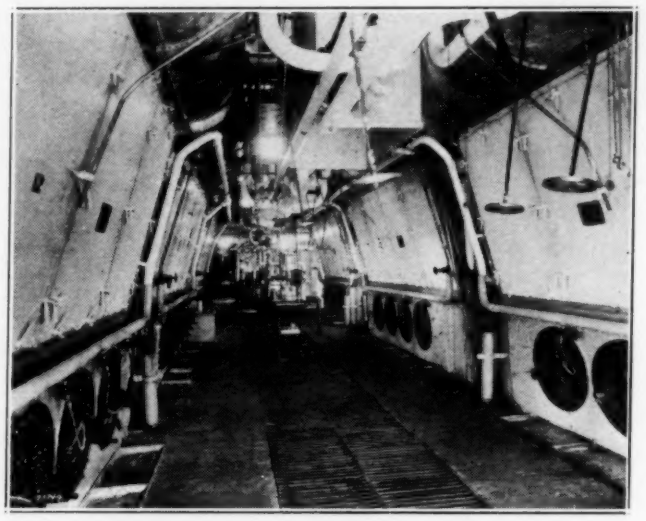


FIG. 15.

steam atomizers and why the mechanical atomizer may with safety be installed on the boiler front, where the air registers are accessible.

Furnace Volume.

The question of impingement may be closely related to the matter of furnace volume because in a small furnace the burner tip must of necessity be closer to the boiler tubes. The tip of a mechanical burner atomizing 800 lbs. of oil per hour may be placed within five feet of the boiler tubes without causing trouble, so long as the boiler is clean, and, as a matter of fact, when firing a marine water tube boiler of the three drum express ("A") type at high rates of heat liberation in the furnace, burners atomizing 1600 lbs. of oil per hour have been located with their tips approximately two feet from the tubes of the boiler without resulting in tube losses.

The size of the furnace to build under any particular boiler will be influenced by the type of burner to be used for firing it. A smaller furnace can be used with a burner producing rapid and complete combustion than with one producing slow combustion and a long flame. Assuming the type of burner to be fixed upon, the question of the size of furnace then becomes one of balancing maintenance against initial cost.

In many cases, there seems to be no necessity for the extremely large furnaces which are often built. When using burners of the mechanical atomizing type, if the volume of the furnace is properly distributed, there should be no difficulty in liberating continuously 60,000 BTU per cubic foot of furnace volume per hour. In a marine water tube boiler of the "A" type, a heat liberation of nearly 300,000 BTU per hour per cubic foot of furnace volume has been obtained. It is quite common in the express type boilers used in the Navy to operate at rates of liberation approaching 200,000 BTU per hour. The

smaller the furnace, the less the initial expense and the lower the radiation.

The question of increasing the amount of heat liberation in the furnace brings to the fore the type of furnace that shall be employed in order to avoid excessive maintenance. In the ordinary boiler furnace, the walls are in "sight" of the tube bank and are cooled by radiation from the walls to the heating surface of the boiler. In certain industrial applications, in order to reduce the furnace temperature, fuel is burned with a high excess of air or the flue gases may be recirculated to accomplish this purpose. While the decrease in furnace temperature is made primarily on account of the process involved, it also decreases the furnace maintenance.

A large furnace volume is not necessarily an indication that the furnace maintenance will be low. If the burners are set under extension arches, and out of "sight" of the boiler tubes, a higher heat liberation may be possible than if the extensions are removed and all of the furnace is brought in "sight" of the tube bank.

Refractory Furnaces.

The maximum "combustion density" or heat liberation per cubic foot of furnace volume permissible in an ordinary solid brick setting when using a mechanical burner depends on a great many factors. The shape of the furnace and the load factor of the boiler and the method of operation all have a large influence so that each installation must be considered as a special case. If the furnace is properly arranged, a heat liberation of 50,000 BTU per cubic foot should give no trouble.

In any setting formed of fire brick the installation must be made properly to provide for expansion and the brick must have a suitable composition in order to have a long life in the atmosphere which exists in the furnace. Also, in many industrial furnaces, in order to obtain a proper heat distribution throughout, it is necessary to give particular attention to the point at which the exit gases are removed. Otherwise some of the product may not be heated sufficiently and some of it may be overheated.

Air Cooled Walls.

In order to reduce the radiation losses and give a longer life to the refractories forming the furnace, air-cooled walls are often used. The brick forming the modern air-cooled furnace walls is often supported by being attached to steel members outside of the boiler setting. Also, provision is usually made for expansion. It should be remembered that the only thermal gain accomplished by an air-cooled wall is through the reduction of the radiation losses from the furnace, although in certain cases it has been considered that combustion has been speeded up due to some pre-heating of the air passing through the ducts in the walls. Such walls are more expensive to build than a solid refractory wall but they are often justified where unusually high settings are used and the load on the brick in the lower parts of the walls would be excessive.

Water-Cooled Furnaces.

The water-cooled furnace was introduced largely for the purpose of decreasing furnace maintenance when burning coal. It probably received its greatest impetus due to the fact that the chemical properties of the ash from coal would often cause it to flux with the brickwork of the furnace. The first cost of a water wall is greater than for air-cooled walls but its greater permanence and the fact that a certain amount of water cooling in the furnace may afford the most economical arrangement of the total heating surface has greatly stimulated this type of furnace construction.

There are a number of modern boiler installations in which oil is fired into a so-called "black furnace." A common illustration to show that the "black" furnace is entirely practicable with oil burning is the Scotch marine boiler with its entirely water-cooled furnaces of comparatively small volume. However, in the Scotch boiler furnace the "combustion density" is greatly in excess of that ordinarily encountered in the "black" furnaces of boilers in stationary plants. In such furnaces, at low rates of heat liberation per cubic foot of furnace volume, it may appear to the operator accustomed to seeing an oil fire in a refractory furnace that the flame does not have the best possible appearance. However, this is generally a case of visual deception as it has been found that even at low rates of heat liberation the actual results obtained are excellent. There are many different forms of this type of furnace construction.

Refractory Faced Water Walls.

Water walls of this character have cast iron blocks bolted tightly to the tubes forming the walls of the furnace. (See Fig. 10). There is often provided a special pad between the blocks and the tubes in order to promote rapid heat transfer which could not be obtained if the block fitted the tube loosely. These blocks are faced on the furnace side with a refractory material. The idea in this type of furnace is that the benefits of water cooling can be obtained but at the same time there is a refractory facing to radiate heat to the flame. In certain instances cast iron blocks are used without the brick covering, close contact with the water tubes preventing the blocks from burning.

Forced and Natural Draft.

While certain types of oil burners can be used, with either forced or natural draft, the latter is usually supplied in small plants. In fact, in those types of heat treating furnaces where steam or air atomizers are usually employed, natural draft is used exclusively. By the use of forced draft in burning oil at high capacities, the furnace may be maintained at approximately atmospheric pressure and excessive air infiltration avoided. Also, where forced draft is used, the stack may be smaller in size as it is required only to overcome the draft loss through the boiler and the breeching.

The modern power plants almost always employ forced draft, especially when preheated air is used. Figs. 11, 12 and 13 show installations of this type

in which the air for combustion is introduced into a double front or windbox surrounding the air register. Provision is made for removing and inserting the burners, setting the air doors and inspecting the fires from the outside. Marine installations are often laid out in this way. (See Figs. 14 and 15). In the Navy, however, closed fire rooms are used and the air is forced into these under pressure.

Preheated Air.

With forced draft operation at the higher rates of capacity the flue gases often leave the boiler heating surfaces at a relatively high temperature. In such cases, it has become quite common to install a waste gas air preheater to reduce the temperature of the gases discharged into the stack and at the same time preheat the air for combustion. This increases the efficiency of the unit and in the case of a small furnace, may assist the operation by increasing the rapidity of combustion. There is no economic gain in taking heat for preheating air away from the furnace itself in spite of arguments which have been advanced to the contrary.

With highly preheated air, the draft losses are considerably greater than with air at atmospheric temperature. It is a fact that if the air temperature is increased from 70 deg. to 600 deg. F., the air pressure required to force the same weight of air through the register is practically doubled. Also, it is necessary to guard against radiation from ducts and windboxes not only because this is a direct heat loss but also because it may make the fire room an extremely uncomfortable place in which to work.

With the ordinary type of air register front plate, a very large section of the windbox outer plate will be uninsulated allowing excessive radiation. A very satisfactory design is obtained by constructing the front plate of the air register in the form of a rectangular box and filling the box with insulating material. This is shown very clearly on Figs. Nos. 12 and 13. This type of construction permits the windbox plates being made in sections and bolted to the flange of the air register front, thus allowing for expansion. The section of the plate in between the burners may be covered with insulating material and in this way, the whole windbox will have a continuous coating of insulation.

Guarantees.

A burner should be purchased from a reputable manufacturer and suited to the shape of the furnace and the atmosphere desired therein. If the burner is purchased under such conditions and installed and operated as the manufacturer recommends, a satisfactory installation will result. Close scrutiny should be given to any excessively high guarantees of efficiency and statements that large savings can be made without regard to the type of installation or the method of operation which it is desired to improve. It is a very true statement that a plant cannot be run on guarantees.

In the case of the boiler, it hardly seems reasonable that an oil burner manufacturer should be called upon to guarantee the overall boiler and furnace efficiency any more than he could be expected to guarantee the speed of a horse if he did not know to what type of vehicle it was hitched. What he can guarantee is the combustion efficiency. That is, the quantity of fuel to be burned per hour, complete combustion without smoke and a specified amount of excess air in excess of the theoretical requirements. When this guarantee is met, it depends upon the effectiveness of the boiler heating surfaces as to what overall efficiency will be obtained from the unit.

Efficiency itself means nothing unless it is coupled with economy. It should be remembered that through the burner there passes the fuel which represents probably the largest operating cost for running a plant and there is no economy in purchasing unsuitable equipment having a low first cost when an original saving may be more than overcome by the waste of fuel in operation.

The importance of proper burner design has been recognized by many of the largest oil producers who have found it desirable from an economic standpoint to purchase improved types of burners for firing their waste fuels. The fact that such fuels are available at no extra cost is no reason for firing them with obsolete and uneconomical equipment.

There are many factors which enter into the determination of the efficiency of a unit. With the boiler, if the proper instruments are available for making a complete test, it is quite possible to determine accurately the ratio of the steam produced to the fuel supplied. In industrial furnaces the conditions are generally somewhat more variable and the efficiency is usually determined by the amount of product which is produced per unit of fuel supplied.

In any event, in making an efficiency determination, it should be ascertained that all of the factors and quantities entering into the test have been accurately determined, otherwise, such tests are of little value.

Automatic Control.

In some installations it is extremely desirable to provide full or semi-automatic control in order to regulate some or all parts of the process. There are a number of successful automatic combustion control systems on the market; however, many of them are complicated and expensive and it must be remembered that an automatic control does not relieve the operators of all responsibility and is effective only if it is kept in operating condition. If the control is so complicated that the plant operators cannot adjust it, it is a waste of money to install it.

In any event, for the most satisfactory results sufficient instruments should be provided to enable the operators to determine accurately the operating conditions. It is desirable to have the pressure and draft gauges and thermometers showing the condition of the fuel and air delivered to the burners located on a central control board where flow meters and any other indicating devices are placed. See Fig. 13.

Auxiliary Equipment.

Also, there must be provided auxiliary equipment for delivering the fuel to the burners properly strained and at the correct temperature and viscosity. Oil storage tanks of suitable size will be installed and the arrangement and size of these will depend on

local conditions. These tanks usually will be fitted with a drain from the lowest point to remove water or sediment and a high and low suction line. Under normal operating conditions, the low suction will be used. If water or other non-combustible matter collects in the bottom of the tank at the level of this line, a change can be made to the high suction usually located a foot to 18" above the low suction and operation continued without interruption. The water may then be removed after which the low suction can again be used.

Steam coils should be provided in the tank if heavy viscous fuels are being used so that the oil may be heated to such a viscosity that it will flow readily to the pumps. These coils are often located in a wooden box in the bottom of the tank so that all of the oil going through the suction line first passes through the box and over the coils. The box design prevents an undue amount of radiation from the coils to the main body of oil in the tank.

Between the tank and the pumps there is generally provided a suction strainer of the duplex type for removing any large particles which might interfere with the operation of the pumps.

The suction line between the tanks and the pumps should be so arranged that there are no places in it where gas may collect, and it should be of such a size that there is not an excessive pressure drop. If the tanks are located at a great distance from the point where the oil is to be consumed, so-called "booster" pumps may be provided to deliver the oil at low pressure into the suction of the service pumps.

Fuel oil service pumps are usually installed in duplicate and may be of the reciprocating, rotary or screw type and driven by steam or electric motors. It should be ascertained that they are properly fitted for handling oil at the pressure temperature and viscosity to be used and that they will operate satisfactorily under the suction conditions which will be imposed upon them. These pumps supply oil at the proper pressure to the fuel oil lines connected to the burners, and should be fitted with governors, relief valves and necessary vents for entrained gas or air. The pumps should deliver the fuel at a prsesure sufficient to take care of the pressure drop through the auxiliary equipment and the pipe lines and pro vide the desired pressure at the furnace front.

If the pumps are of the type which do not maintain a steady discharge pressure (which is absolutely essential for most efficient operation of the burners) an air chamber of liberal capacity should be located on the discharge of the pump to smooth out fluctuation in the pressure. The inlet and outlet connections should be so attached to the air chamber so that the full benefit of the air cushion is obtained.

In order to maintain the oil at the proper viscosity, which is essential for correct atomization, oil heaters are usually provided. These are generally steam heated and in duplicate. They should be fitted with air vent valves so that any entrained air may be removed from the steam space and with steam traps which will keep them free of condensate. Usually two heaters are provided, each one of which has a capacity to take care of the maximum plant load.

From the heaters, the oil usually passes to a discharge strainer of the duplex type. The bonnets on this strainer are generally of the bolted type.

The oil lines should be of such a size that there is not an undue pressure drop through them and the joints should be made up of material which is not affected by hot oil.

Conclusion.

Successful results from any given equipment for burning liquid fuel depend upon the installation and operation. The equipment should be installed and the fuel and air should be delivered to the burners under the conditions specified by the manufacturer. All of the equipment should be kept clean and in operating condition. There is no reason why a plant burning liquid fuel should not be almost spotless.

The operating results can be checked by proper instruments and by visual appearance of the furnace. In the case of a boiler, the setting should be kept tight to prevent infiltration of air and the boiler surfaces should be kept clean inside and out.

It is easy to burn liquid fuel economically with a little care and attention. However, carelessness in operation can produce extremely wasteful conditions even with the best of equipment.

SPECIAL FEATURES

CONVENTION AND EXPOSITION

Wm. Penn Hotel

Get Acquainted Luncheon

Monday Noon, June 17, 1929

Official Opening
Iron and Steel Exposition
Monday, 7:30 P. M., Main Lobby

Informal Reception
Monday Evening, 9 P. M.
Wm. Penn Hotel **Italian Room**

Tuesday, June 18, 1929
Engineering Breakfast
8:30 A. M., Italian Room

Thursday, June 20, 1929
1 P. M. (Daylight Savings Time), Inspection Trip, Jones & Laughlin Steel Corp., Aliquippa, Pa.

7:30, Formal Reception, Italian Room
Featuring
Richard Crooks,
Grand Opera Tenor
Don Bestor,
Victor Recording Orchestra

Some Methods of Best Utilizing Electrification in the Steel Industry

By G. E. STOLTZ*

Progress is something we have with us always, but too often we work along lines which lead us to conclude that we have accepted the order of things as they exist today. It is frequently stated that methods have been established which are being practiced by many people and for this reason it can be assumed that such methods are the most practical for the future. This of course prevails until some individual, who is not willing to accept this philosophy, introduces something which meets our needs better than the old method.

Looking back over history there is nothing so apparent as the fact that conditions change and progress is being made. If we are to keep apace with this natural advance, a certain portion of our

G. E. STOLTZ

time or a part of our organization should be applied to the bringing to the surface new methods which are bound to come sooner or later and the remainder of our effort to routine duties.

During the war we were in a selling market, and the great demand for tonnage built up an abnormal capacity for manufacture which could not be kept at full operation after the war. Individual organizations immediately directed their efforts along lines which in their opinion would bring their operations up to their capacity. Those who were successful accomplished it by introducing new methods or processes which reduced their costs or gave them a product which met their customers' requirements in a more satisfactory manner. Those who continued along old established methods suffered while their more alert competitors prospered. They had simply failed to transfer that great effort to produce large tonnage during the war, to one of improving present methods, introducing new ideas, reducing costs and producing a better or a new product.

The use of electric motors in the steel industry has been one of its outstanding developments in recent years as electrification has assisted in the reduction of costs and the production of better steel. It is one to which the operating companies can point with considerable pride but this does not mean that they should rest on their oars nor should they conclude that this is one of those outstanding developments which seldom, if ever, are paralleled.

The acceptance of the idea of electrification of rolling mills in the steel industry we believe should only be considered as one incident or step in the entire program. There are many important problems still to be developed.

One of the major problems for a number of our steel plants is the disposition to be made of 25 cycle apparatus, which became established before 60 cycle apparatus had been developed to the point where it it suitable for all applications.

Aside from the steel industry the only 25 cycle installations of any moment in the country are located at Niagara Falls and New York City. In New York City we understand the United Electric Light and Power Company have decided that future extensions will be on 60 cycle apparatus only and if one can judge by the amount of frequency converting equipment being installed it is quite possible that future generating plants built at Niagara Falls will be 60 cycles.

Twenty-five cycle power of course is unsatisfactory for lighting. This has been one very strong reason why central station companies have adopted a higher frequency, but aside from this the lower cost of 60 cycle equipment is another very definite reason why 60 cycle should be selected. This is illustrated by the following.

Single Phase Transformers

The following is a tabulation of comparative cost of 25 and 60 cycle Kv-a. single phase transformers:

		Comparative Cost	
Kv-a.	Voltage	60 Cycle	25 Cycle
10	2300/230	$ 108	$ 153
50	2300/230	345	450
1000	6600/460	2600	3940
5000	22000/2200	9400	14000

Motors

The following is a comparative cost of 25 and 60 cycle squirrel cage motors not only at comparable speeds but data is included for 60 cycle motors of higher than 10-pole speeds. It will be

*Mgr. Engr. Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

noted that 60 cycle motors at approximately the same speed as 25 cycle are more expensive on the small horsepower ratings. This is due to the fact that 10-pole 60 cycle winding is expensive for such small ratings.

Plants that are equipped with 60 cycle generating apparatus will in practice select motors of higher speeds than the 4-pole 25 cycle speed. This will result in still greater saving in favor of the 60 cycle installation.

		25 Cycle		60 Cycle		60 Cycle	
H.P.	Voltage	RPM	Cost	RPM	Cost	RPM	Cost
5	220	715	$ 118	690	$ 158	1750	$ 68
10	220	715	203	690	232	1160	129
50	220	715	586	690	538	870	430
100	220	715	985	690	840	870	700
200	220	715	1705	690	1320	870	1295

Generators

Steel mills are now interested in turbines of 10,000 or 20,000 kilowatt capacity which are usually designed for speeds of 1500 R.P.M. on 25 cycle and 1800 R.P.M. on 60 cycle. On this basis the designs of the machines do not differ a great deal, the 60 cycle usually being about 5% cheaper than the 25 cycle. We should, however, not overlook the fact that the speed of turbo generating equipment is being increased as improved material and better balancing equipment are developed. At the present time a 10,000 kilowatt, 60 cycle turbine has just been designed for 3600 R.P.M. Of course this requires very high grade material and very careful balance so that the difference in cost is not much different from that of an 1800 R.P.M. machine. As time goes on and we learn to build this higher speed equipment with greater ease, it is possible that there will be a growing differential between 60 cycle and 25 cycle generators of this capacity.

By far the larger percentage of turbo generators built in recent years is for 60 cycle power. The very fact that the majority of A.C. apparatus built is for 60 cycles means that its design is more advanced than apparatus built for other frequencies. Better performance should be expected from the equipment whose design is modern. The following table gives a comparison of the total capacity of turbo generators built in this country during recent years. In addition to this of course there is a certain amount of generating equipment for frequencies other than 25 or 60 cycle and a small amount of direct current equipment.

	60 Cycle		25 Cycle	
Year	%	Kw.	%	Kw.
1926	84.7	1,716,700	5.6	114,000
1927	84.7	1,640,750	14.65	284,000
1928	94.4	1,458,275	3.1	46,500

Several years ago there was considerable discussion in regard to the feasibility of tying large systems together and forming a super-power system. The advantages of large generating stations tying their systems together were so apparent that the establishment of super-power systems in this country came about naturally without the necessity of any great amount of urge. There is no particular reason why large generating plants in the steel industry should not be tied in with public utility systems. Advantages would be gained by both the public utility and the steel company with such an arrangement. Some of the power companies are establishing new rates which we believe should be attractive to the steel companies, and with these new power rates it may be uneconomical to generate power in excess of that obtained from blast furnace gas. If the steel plants were equipped with 60 cycle apparatus it would be a very simple matter to tie their systems in with the local central station power lines. This would eliminate the necessity of the steel company's having spare capacity and would permit them to divide the total load between the power company and their own plant on the basis which would be most economical to the steel company.

There are various types of fuel used in a steel plant but the most convenient form is gas. In a number of instances blast furnace gas has been combined with coke oven gas for furnaces. We believe there will be a tendency to use blast furnace gas for other purposes than generation of electric power in which case more power will be purchased from public utilities. With this trend in mind 60 cycle installations will be found more practical than 25 cycle.

Since steel has been manufactured there have been continuous efforts to produce a higher quality of product. Particularly during the last fifteen years considerable improvement has been made by the production of alloy steels. The introduction of these alloy steels of course has bettered the physical properties but these improvements have not necessarily been paralleled to the same extent by a scientific treatment of the steel. This phase of the work is now being stressed and we believe there is no question but what there will be an extended use of electric furnaces for melting of steel as well as heat treatment. In electric furnaces, particularly of the induction type, a much better control of the reactions in the bath can be obtained than in an open hearth furnace. The electric furnace of course will not be able to compete where ordinary steel is satisfactory but there is always a certain percentage of very high grade steel that is required and as time goes on it is evident that this percentage of high grade steel will grow. The cost of the metal parts used in an aeroplane are of practically no consequence when weighed with the necessity of obtaining a product which must be uniformly of the very highest grade.

The full advantage of alloy steels is not obtained if heat treatment is not properly handled. Electric heat treating furnaces of course permit very close control of temperatures and should permit the operator to duplicate results obtained in the laboratory.

To an electrical engineer who is accustomed to work with exact measurements and methods, the manufacture of steel seems to depend on a number of indeterminate processes which can hardly be said to be reproduced with any great degree of accuracy. We imagine it is with some difficulty that defects in finished product are laid definitely to some fault in the several processes involved. The adoption of processes such as automatic screwdown on mills or the electric melting or treating of steel should simplify the manufacture of steel. With such exact methods, the likelihood of producing poor steel is reduced and the location of the cause of trouble is made easier.

There should be no effort to oversell the use of electric furnaces for the melting and treating of steel but we should expect a continuous trend towards

higher grade material and as this demand develops the increasing use of such furnaces can be fully justified. The electrical engineers of our steel plants have done a great deal to bring electrification of rolling mills to a reality. One of their future interests should be the introduction of electric furnaces as rapidly as they become practical.

If we were to review the proceedings of the Association of Iron and Steel Electrical Engineers* it would be found that the engineers have made quite a study of the application of electric motors to rolling mills even before electrification was fully accepted, or seriously considered by some. It will be to the advantage of the steel industry if this same study is made of the use of electric furnaces even now before they are given serious thought. A reasonable adoption of electric heat in the steel industry will develop a very large increase in the amount of power required. This will tend to reduce the cost of electric power and will probably mean that most of the large plants will purchase large blocks of power from central stations.

During the war we heard much of welding, particularly on ships, but within the last two years electric welding has been given another impetus. In the manufacture of electrical machinery rolled shapes are being used instead of castings. Stators, spiders and bedplates are being manufactured from plates, bars and structural material all welded together to take the place of castings which were formerly used. This method of manufacture was adopted due to certain limited advantages but with increased experience obstacles that at first confronted us have been overcome. Further advantages have developed which eventually may transcend in importance those which were first apparent and were the ones that caused us to try the fabrications of electrical machinery.

Much of our large machinery is seldom duplicated so that patterns once made have very little activity. Where electric machines are fabricated shorter delivery can be made due to the fact it is not necessary to wait for new patterns and castings; it is a simple matter to modify an existing design to include some improvement when duplicate machines are built or a design can be easily modified to be used on a machine not a duplicate but in many ways similar to the original machine.

It is often desirable to reinforce structural steel buildings or bridges. It may be desirable to add other floors to a building or certain of the members of the structure may have corroded. It is a very simple matter to reinforce these buildings by electric welding. It is often found that railway bridges are not adequately designed for the present equipment and instead of rebuilding the bridges electric welding permits reinforcing which will accomplish the same result with very much less expense. It has been surprising to us that more electric welding is not being done in steel mills not only on the machinery and buildings but also in the manufactured products.

We of course realize that steel companies now are becoming interested in the welding of tubes, plates and structural material, but this is only a start. No doubt there will be some very important developments along this line in the future and they may be just as far reaching as the electrification of rolling mills has been in the past.

Until shortly after the war practically all of the rolling mill motors installed were put on new mills but at this time the steel companies became very active in the installation of motors on existing mills. Sometimes new mill housings were installed with a new motor, but often the motor simply replaced the engine, no material change being made in the mill. It is of course recognized that the instant electrification has been accepted as the correct method of driving mills that we should not expect all engines to be removed immediately. In general we feel that electric drive is being introduced in the steel industry as fast as could logically be expected; however, there are some programs of electrification that have been deferred due to the fact that at some future time the design of the mill layout would have to be changed and it is felt that it would not be practical to replace the engine with a motor until this new design is developed. It is recognized that if a motor were installed on a mill and operated for a period of ten years that a re-design of the plan of the mill might be such that the motor could not be used. For this reason no steps have been taken in replacing the steam engine. We do not believe that this line of reasoning is correct. We have in mind a steam engine driven blooming mill where the company has been weighing the desirability of installing a motor in place of the engine for a period of ten or twelve years. It has always been deferred on the basis that they sometime will need to install a new mill. The cost of the electrical equipment completely installed would be in the neighborhood of $480,000 and it is agreed that the return on this investment will be $240,000 per year so that a complete return on the investment would be accomplished in a two year period. If this installation had been made say ten years ago this mill would have had an increased income of approximately a quarter of a million dollars per year. If it should happen that this motor could not be utilized at the end of a ten year period when a new plan of mill would be adopted, this company could scrap the motor without any regret if necessary as it would have paid for itself many times. There are not many places where money can be invested with such a definite and liberal return assured, and there should be no sentiment against discarding a motor in good condition if the interest of the company is better served by having done this.

During the early period of the application of motors to rolling mills considerable thought was given to the design of the motor and control equipment used and we believe that as a rule the manufacturer who incorporated the best engineering in their proposal obtained the business. At that time there was an excellent opportunity for suggesting advanced ideas which of course would result to the advantage of the purchaser. Later there has been a growing disposition to place this business not on an engineering basis but with greater stress placed on reciprocal relations. There have been instances where some manufacturer does a great deal of engineering work that is of considerable value to the purchaser and after all this preliminary work is completed specifications are re-issued incorporating these new ideas, and the business is then awarded on

*Iron and Steel Engineer.

reciprocal relations or low price to a company, who to all intents and purposes is not capable of solving or particularly interested in the purchaser's problems.

Manufacturers in general quickly adjust themselves to changing conditions and if business is to be placed on a low price or on a reciprocal basis, they are bound to shift their efforts from engineering to that of proposing equipment which can be disposed of at low prices.

Many of our steel mill contracts are of the order of one-half million dollars for the main drive electrical apparatus alone. We can hardly conceive of an installation of this magnitude that does not require some very careful and skilled engineering which of course entails considerable engineering risk to the reputable manufacturer. Still, odd as it may seem, some of these contracts are placed on the basis that all bidders, regardless of their experience or the assistance they have given during the negotiation stage, are placed on the same basis and the business awarded to the lowest bidder.

The steel industry has this situation very largely in their own hands and I do not want to leave any impression other than it has been very aggressive in the past and in general it may be said that it has rewarded its manufacturers for their participation in development work; however, it can only hold its place by continuing to encourage the development of new methods and new processes. Failure to do this will react against the industry. Our purpose in bringing this to your attention is to urge that you continue the very fine record this industry has enjoyed in the past and that you reward those who contribute to the industry's advance, whether they be within your organizations or outside. Manufacturers can be of considerable assistance but you will fail to get their best efforts if their work is not given recognition. There is no reason why the romance connected with this industry should not still be greater but it will be necessary to continue to press forward without any relaxation.

Progress in Instruments and Control

By J. W. JONES*

The steam requirements of the average steel works power house are quite variable, due to the irregular power output of large motors and for this reason automatic combustion control is particularly desirable to regulate the quantity of fuel burned in

J. W. JONES

the boiler furnaces. A good control system is one that immediately acts to supply fuel together with the proper quantity of air, and draft sufficient to carry away the products of combustion, in proportion to the demand for steam.

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The modern large steam generating unit is economically adaptable to automatic control with an accuracy much greater than in the past. During the past year there have been a number of plants discard their small obsolete boilers and replace them with modern high pressure boilers, taking advantage of the many improvements that have been made in boiler and combustion equipment. The increasing use of large motors for driving mills has created a demand for larger power plants usually located where blast furnace gas is available for use under boilers. This arrangement usually requires the use of an auxiliary fuel to furnish necessary steam during times of gas shortage and the automatic control equipment must increase the feed of fuel together with the air necessary for proper combustion to maintain a practically constant steam pressure. A very recent example of this condition is the installation of a modern steam plant at the Youngstown Sheet and Tube Co. The fuels used are blast furnace gas and powdered coal with a control arranged to supply additional fuel and air as the steam pressure drops.

With large units a control panel is usually provided for each boiler, and all instruments such as steam flow meters, draft gauges, pyrometers for stack temperature, stoker or fuel feed tachometers, carbon dioxide recorders, etc., are located together with hand controls for making adjustments to one unit without affecting the adjustments on other units. The unit panel is influenced by a centrally located, steam pressure actuated master panel, from which all boilers are operated in accordance with the steam demand. This arrangement leaves the operator free to supervise furnace condition and make such hand adjustments as may be necessary as determined by an inspection of the fires or read-

ings of the instruments on the various boiler control panels. As a result the average efficiency obtained on the modern automatically controlled boiler is equal to test efficiency.

During the year, refinements have been made in many of the control systems on the market, tending to make them more reliable and automatic with a minimum of supervision or manual control.

Developments in carbon dioxide recorders and steam flow meters have been principally along the line of improvements in design and construction, looking toward increased dependability and convenience in servicing. A well known meter company are introducing a new type of recorder which will have a uniformly graduated chart and can be used for a maximum of four records; two of flow, one of pressure and one of temperature. For example, on a single chart a record of flow in either direction in a given steam line, plus steam pressure and steam temperature can be supplied. This sort of combination is often of much value in the steel mills to show the interchange of steam in the tie line between two boiler houses.

Another recent development of this company is a control pyrometer, which is complete within itself and in many of the applications to which it may be adapted, it requires no auxiliary relay apparatus. The outstanding feature of this control lies in the elimination of all metallic contacts, which have been the weak link in control practice to date. These are replaced by a gas-filled mercury contacter switch, particularly suited to handle high currents.

Metallurgists are beginning to realize more every day that the accurate control of the flame in an open hearth furnace is necessary for a knowledge of reactions taking place between the slag and metal. The open hearth furnace which is one of the most difficult units to regulate is now being furnished with automatic control to proportion the quantity of air to gas and also to maintain a constant draft on the furnace. The control can be adjusted to change the character of the flame by a simple arrangement which permits the heater to use one flame for melting and another for working the heat. While this type of control is more easily applied to furnaces using coke oven or natural gas, it has also been designed for application to furnaces using producer gas.

The advantages claimed for this equipment are that the furnace has been speeded up, the cost of repairs reduced, while the life of the furnace has been increased. Installations of this type of open hearth control made recently have proven that good operating conditions can be maintained and the fuel required per ton of steel can be reduced.

Progress has been made in the development of a control system for open hearth furnace operation. Trial runs have shown marked improvement in fuel consumption per ton together with an increase in output, while the life of the roof and checkwork has been lengthened. The use of reversing valves has been eliminated and air is supplied to the furnace with a positive control of air and draft.

In heating furnace operation there is a fuller realization of the value of better combustion control and the necessity of obtaining it by means of automatic equipment in order to conserve fuel and also to reduce oxidation on the metal being heated. The use of automatic devices for proportioning the fuel and air mixture, in conjunction with automatic draft regulators, is employed to accomplish this result.

The necessity of accurate temperature control in the continuous type furnace for normalizing sheet steel has caused the development of several types of temperature regulation. Some furnaces are divided into several zones, the temperature of each zone being automatically regulated by a control pyrometer. A further development is the application of a radiation pyrometer to control the speed of furnace rollers to maintain a contsant temperature in the sheet.

A prominent burner company have developed a magnetic type of automatic shut off valve to be applied to systems using motor operated blower or compression equipment when used in conjunction with oil or gas. Any interruption in the electric current to the motor releases a latch normally held engaged by a magnet and the weighted arm of the valve lever closes the valve.

The combustion engineer has occasion often to make tests of waste flue gases or of unburned gases present in furnaces. A new style engineer's model of portable gas analysis apparatus has been designed and adopted as standard by the Committee of Chemists of the U. S. Steel Corporation. This apparatus is supplied with three absorbtion pipettes of an improved design and a slow combustion pipette for the determination of ethane, methane, and hydrogen. This feature is useful in testing the unburned gases in furnaces having a reducing flame. The development of a solution to be used in this apparatus for absorbing oxygen, called "Oxsorbent," increases the speed and accuracy of the measurement of oxygen present in a gas sample. Another solution called "Cosorbent" is just as efficient in giving a quick and accurate determination of carbon monoxide in the sample.

In conclusion, it may said that the intelligent application and use of many of the various instruments and control systems assist materially in decreasing fuel costs and at the same time to increase production and quality of steel products.

Report of the A. I. & S. E. E. Special Committee on Bearings

By F. D. EGAN*

ANTI-FRICTION BEARINGS

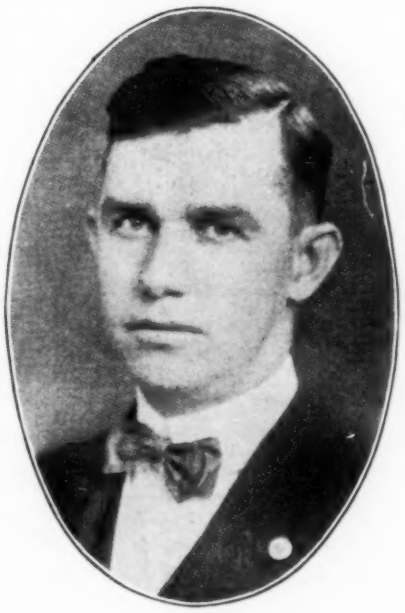
It is the purpose of the Special Committee on Bearings to collect, tabulate and publish in the proceedings of the Association,† such data as is available on application of Anti-Friction Bearings in the Steel Industry. In this endeavor, the investigations and reports will be confined to the following topics, and reports will be published in sequence as outlined.

Part I—The application of Anti-Friction Bearings to Mill Type Motors.

Part II—The application of Anti-Friction Bearings to General Purpose Motors.

Part III—The application of Anti-Friction Bearings to Electric Overhead Traveling Cranes.

Part IV—The application of Anti-Friction Bearings to Mill Roll Necks.



F. D. EGAN

Part I— Application of Anti-Friction Bearings to Mill Type Motors.

This report is made up of a tabulation of the Anti-Friction Bearing and Motor Manufacturer's recommendations in Roller Bearings sizes for application to Armature bearings of Westinghouse Electric & Manufacturing Company, General Electric Company, and Crocker Wheeler, Mill Type Motors. The report includes available data on bearing sizes and lengths, as well as shaft and housing fits for the enlightenment of the Mill Motor trade. A paper by C. W. Lange of General Electric Company, giving complete mechanical details for adaptation of Roller Bearings to G. E. Company's MD Motors, is included, and credit is extended to them for this courtesy and co-operation.

Considerable difficulty has been encountered in making up a report of this kind, inasmuch as information available in the Bearing Manufacturer's catalogues is not complete in many instances, and must be supplemented with additional information obtained through correspondence with the various Bearings and Motor Manufacturers. Complying with our request for information, the Rollway Bearing Company, Norma Hoffmann, SKF Industries, Timken and Hyatt Bearing Manufacturers, together with Crocker-Wheeler, General Electric Co. and Westinghouse Electric & Manufacturing Co. gave complete resumes of Bearing sizes and dimensions which are listed in the tabulation.

In order to establish a basis for comparison, the Motor frames are listed in relation to their rated torque. It will be noted that there is a total of forty-three frames, ranging in torque from 22 to 4430 ft.-lbs. with no two frames having exactly the same rated torque. General Electric Company has the greater number of frames in the small motor sizes, which is brought about by the fact that both the old G. E. MD 100 series motor and the new G. E. MD 400 series Motors are included in the tabulation.

In a previous report, the Standardization Committee of the Association has recommended the adaption of the 300 series roller bearings for Mill Type Motors up to 75 Horsepower. The Motor Manufacturers have followed these recommendations, with the following exceptions:

1—Hyatt is recommending the 200 series bearing for the General Electric MD-100 line of Motors. Rollway, SKF, Norma Hoffmann, and Timken are recommending the 300 series Bearings for these frames.

2—Hyatt is recommending the 200 series bearing for Crocker-Wheeler Frame CW, EW, FW, GW, HW, and IW Frames.

3—Norma Hoffmann's tabulation shows the 400 series bearing for the following frames, Crocker-Wheeler EW, FW, GW, General Electric MD 106, MD 107, MD 414, MD 416, MD 418, Westinghouse MC 80, MC 90, MC 100, and MC 103. This bearing in actual dimension however, is the 300 series bearing.

The matter of departure from the 300 series bear-

*Chairman Special Committee on Bearings. Electrical Superintendent, Bethlehem Steel Co., Lackawanna, N. Y.

†Iron and Steel Engineer.

ings in these motor frames is referred to the Standardization Committee for consideration and recommendations, for approval of existing practice or further standardization of these frames. No attempt will be here made to submit recommendations for standardization, inasmuch as it is the purpose of this report, only to compile and tabulate the present data and practices.

Table "A" shows typical cuts of Hyatt, Rollway, SKF, Timken, and Norma Hoffmann bearings in the types adapted to the Mill type Motors, and gives a comparison of Bearing Bores, O. D.'s, Lengths, Rollers, etc., which are recommended by the Bearing and Motor Manufacturers.

Tables B and B-1, show actual dimension fits for W. E. & M. Co. Type MC and Crocker-Wheeler type W motors, and indicate the diversity in fits recommended for various manufacturers' Bearings. Bearing fits for General Electric Motors are listed in Table A.

In order to satisfy the customer's requirements and specifications as to Manufacturer's Bearings, and at the same time, provide as complete interchangeability as possible, Westinghouse has developed a Universal bearing cartridge for the MC Motors, which accommodates either Hyatt, Rollway, SKF, Timken or Norma Hoffmann bearings in the same cartridge, with necessary adapters for Thrust, Float and different bearing lengths. The Westinghouse tolerance in fits is listed in Table "B" under Westinghouse adaption.

Maximum and minimum fit implies the accepted range in tolerance and is designed as either "Plus" or "Minus" as the case may be. "Plus" in all cases, meaning looseness or slip fit, and "Minus" meaning interference of press fit. "Maximum fit" occurs with maximum shaft diameter and minimum bearing bore or Maximum bearing O. D. with Minimum Housing bore. In the same way Minimum Fit occurs with Minimum shaft diameter and Maximum bearing bore or Minimum bearing O. D. with Maximum housing bore. An inspection of fits in Table "B" shows a "Minus" or press shaft fit in all instances, with one exception under Westinghouse Adaption for the 313 bearing, where Minimum fit is Plus .0001. In Cartridge fits, Westinghouse tolerance is plus or slip fit in all cases. Hyatt tolerance range from "Minus" or press fit to "Plus" or loose fit.

There is considerable diversity of opinion on the question of Lubrication for anti-friction bearings as applied to Mill Type Motors, as was evidenced in the general discussions at various meetings of the Special Committee on Bearings. In order to obtain a general opinion on the subject, the following questionnaire is being circulated in the Steel Industries, and a resume of the recommendations submitted in reply, will be published in an ensuing report of the Special Committee on Bearings. (See Iron and Steel Engineer.)

Questionnaire

1. How often should ball or roller bearings in Mill Motors be lubricated when operating under more or less normal conditions?

2. How much grease should be added when motors are lubricated? Is there any definite way of determining how much grease to add and at what intervals?

3. Should the frequency of lubrication be increased when motors are working under abnormal conditions, such as subject to heat from outside source; or should this condition be taken care of by a different grade of grease?

4. To what extent is grease leakage experienced?

5. What type of grease has been found the most suitable for Ball or Roller Bearing Lubrication?

6. Should standard specifications be provided so as to arrive at Uniform conditions?

7. What methods are used to insure that only ball or roller bearing grease will be used for bearings?

8. How often should motor bearings be thoroughly flushed and cleaned of grease residue?

9. How often should bearings be disassembled for inspection of bearings and grease?

10. What is variation in temperature in which motor operates throughout a year? Is it practical to draw specifications for a grease that would suit all conditions?

11. Is it advisable to place the greasing of motors under one head to obtain uniformity of practice?

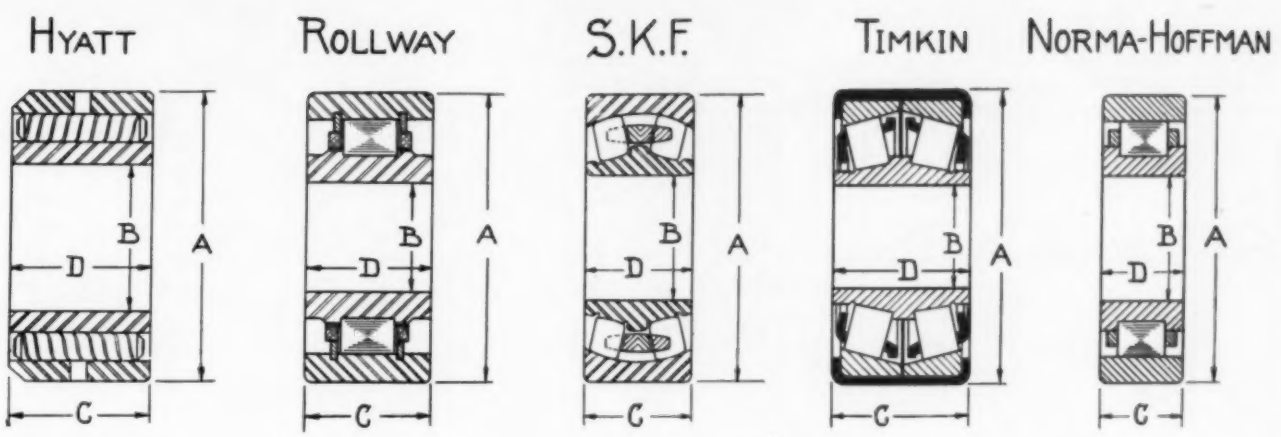
12. What system of greasing motors, do you favor? Grease cup application or gun application?

13. Do you consider it advisable to occasionally overgrease Roller bearings in order to partially flush out worn grease and cleanse the labyrinths of foreign substances that may have collected?

14. Is objectionable heating of bearings experienced on account of overgreasing?

In connection with the topic of lubrication, the Special Committee on Bearings approved bearing housing construction with a series of multiple V grooves for grease seal, to keep the lubricant inside the bearing, in preference to a felt seal bearing. It was also considered preferable for construction to use lugs on the bearing cartridge to prevent turning in the motor housing, in place of dowel pins.

Credit is extended to all the members of the committee and the manufacturers representatives who assisted in the compilation of this report.



MOTOR DATA						BEARING DATA											
M'F'G.	FRAME	TORQUE	H.P.	R.P.M.	MIN. PIN. DIA.	M'F'G.	SERIES	A	B	C	D	ROLLERS Nº	ROLLERS DIA	SHAFT FIT	CART'G. O.D.	FRAME BORE
						HYATT	W-209	3.3477 3.3465	1.7718 1.7711	1.562 1.555	1.5625	20	.375	.0015 TIGHT .0003 "	4.5025 4.5010	4.5000 4.4995
						ROLLWAY	MDW309	3.9370 3.9362	1.7717 1.7712	.9843	1.5625	18	.50	.0010 " .0003 "	3.375 3.372	3.3750 3.3745
						S.K.F.										
						TIMKIN										
G.E.	MD-101	22	4	975	4.00	NORMA HOFFMAN	R-345	3.937	1.7718	.984	.984	12	.50	.0010 TIGHT .0003 "	3.375 3.372	3.3750 3.3745
						HYATT	" 309	3.9383 3.9370	1.7718 1.7711	1.5625	1.5425 1.5325	14	.625	.0015 " .0003 "		3.9378 3.9373
						ROLLWAY	MS-5309	3.9370 3.9362	1.7717 1.7712	1.5625	1.5625	12	.50	.0010 " .0001 "		3.9402 3.9387
						S.K.F.	22309	3.9370 3.9362	1.7717 1.7712	1.4173	1.4173	28	.55	.0014 " .0004 "		3.9378 3.9373
						TIMKIN	8309	3.9370 3.9362	1.7717 1.7712	1.5675 1.5575	1.5675 1.5575			.0014 TIGHT .0004 "		3.9378 3.9373
G.E.	MD402	29	5	900	3.75	NORMA HOFFMAN	R-345	3.9370 3.9364	1.7715 1.7713	.984 .982	.984 .982	12	.50	.0013 " .0002 "		3.9378 3.9375
						HYATT	" 310	4.3328 4.3306	1.9695 1.9688	1.75	1.75	14	.6875			
						ROLLWAY	MS5310	4.3307	1.9685	1.75	1.75	13	.50			
						S.K.F.	52310	4.3307	1.9685	1.5748	1.75	28	.63	-.0010 -.0009		
						TIMKIN	8310	4.3307	1.9685	1.75				.0013 TIGHT .0003 "		
W.E.M.	MC-20	44	6	700	3.50	NORMA HOFFMAN	WIR350-L	4.3307	1.9685	1.063	1.75	12	.5625			
						HYATT	" 311	4.7258 4.7244	2.1656 2.1648	1.9375	1.9175 1.9075	15	.6875	.0017 TIGHT .0004 "		4.7253 4.7248
						ROLLWAY	MS-5311	4.7244 4.7236	2.1654 2.1649	1.9375	1.9375	14	.50	.0011 " .0001 "		4.7276 4.7256
						S.K.F.	22311	4.7244 4.7236	2.1654 2.1649	1.692	1.692	28	.67	.0016 " .0006 "		4.7253 4.7248
						TIMKIN	8311	4.7244 4.7236	2.1654 2.1649	1.9425 1.9325	1.9425 1.9325			.0016 TIGHT .0006 "		4.7253 4.7248
G.E.	MD403	49	7½	800	4.25	NORMA HOFFMAN	R-355	4.7244 4.7238	2.1656 2.1650	1.142 1.140	1.142 1.140	13	.5625	.0015 TIGHT .0004 "		4.7253 4.7248
						HYATT	MW 211	3.9384 3.9369	2.2500 2.2492	1.8125	1.8125	21	.4375	.0010 " .0008 "	4.8140 4.8125	4.8125 4.8120
						ROLLWAY	MDW312	5.1181	2.3628 2.3616	1.2205	2.125	20	.593	.0012 " .0003 "	4.002 4.000	4.0000 3.9995
						S.K.F.	22312	5.1181	2.3622	1.811	1.811			.0012 " .0003 "		4.002 4.000
						TIMKIN										
G.E.	MD102	54	9	875	4.75	NORMA HOFFMAN	R-360	5.1181	2.3622	1.220	1.220	12	.625	.0012 TIGHT .0003 "	4.002 4.000	4.0000 3.9995
						HYATT	T-310	4.3320 4.3307	2.0008 2.0000	1.75	3	14	.6875	.0015 TIGHT .0002 "	3.939 3.938	3.940 3.938
						ROLLWAY	MDW311	4.7244 4.7236	2.1654 2.1649	1.1417	1.9375	22	.50	.0021 " .0006 "	3.940 3.938	"
						S.K.F.	22310	4.3307	2.0005	1.575	1.575	28	.63	.0015 " .0005 "	3.938 3.936	"
						TIMKIN	8311	4.3307 4.3299	1.9685 1.9680	1.750	1.750			.0013 TIGHT .0003 "		"
C.W.	A.W.	64	8	670	3.80	NORMA HOFFMAN	R-355-L	4.7244	2.1654	1.142	1.142	13	.5625	.0021 " .0006 "		"
						HYATT	" 311	4.7258 4.7244	2.1656 2.1648	1.9375	1.9175 1.9075	15	.6875	.0017 " .0004 "		4.7253 4.7248
						ROLLWAY	MS-5311	4.7244 4.7236	2.1654 2.1649	1.9375	1.9375	14	.50	.0011 " .0001 "		4.7276 4.7256
						S.K.F.	22311	4.7244 4.7236	2.1654 2.1649	1.692	1.692	28	.67	.0016 " .0006 "		4.7253 4.7248
						TIMKIN	8311	4.7244 4.7236	2.1654 2.1649	1.9425 1.9325	1.9425 1.9325			.0016 TIGHT .0006 "		4.7253 4.7248
G.E.	MD404	72	10	725	4.50	NORMA HOFFMAN	R-355	4.7244 4.7238	2.1656 2.1650	1.1420 1.1400	1.1420 1.1400	13	.5625	.0015 " .0004 "		4.7253 4.7248
						HYATT	TW-213	4.7260 4.7243	2.5019 2.5010	2.0625	3.50	22	.50		5.7515 5.7500	5.7500 5.7495
						ROLLWAY	MDW313	5.5118	2.5591 2.5585	1.2992	2.3125	20	.625	.0012 " .0003 "	4.7520 4.7500	4.7500 4.7495
						S.K.F.										
						TIMKIN										
G.E.	MD103	86	13	800	5.25	NORMA HOFFMAN	R-365	5.5118	2.5591	1.299	1.299	14	.625	.0012 TIGHT .0003 "	4.7520 4.7500	4.7500 4.7495
						HYATT	" 313	5.5135 5.5116	2.5603 2.5594	2.1875	2.1875	15	.8125			
						ROLLWAY	MS5313	5.5118	2.5591	2.3125	2.3125	14	.625		4.627 4.625	4.628 4.625
						S.K.F.	52313	5.5118	2.5591	1.8898	2.3125	28	.75	-.0014 -.0002	"	"
						TIMKIN	8313	5.5118	2.5591	2.3125				.0016 TIGHT .0003 "	"	"
W.E.M.	MC30	90	12	700	4.29	NORMA HOFFMAN	WIR365-L	5.5118	2.5591	1.299	2.3125	14	.625		"	"

TABLE A-1

Motor Data						Bearing Data												
M'f'g.	Frame	Torque	H.P.	R.P.M.	Min. Pin. Dia.	M'f'g.	Series	A	B	C	D	Rollers No.	Rollers Dia.	Shaft Fit	Cart'g. O.D.	Frame Bore
G.E.	MD406	121	15	650	5.00	Hyatt	"313	5.5133 5.5118	2.5603 2.5598	2.1875	2.1675 2.1575	15	.8125	.0019 Tight .0005 "		5.5128 5.5123
						Rollway	MS-5313	5.5118 5.5110	2.5591 2.5585	2.3125	2.3125	14	.625	.0013 " .0002 "		5.5150 5.5130
						S.K.F.	22313	5.5118 5.5110	2.5591 2.5585	1.890	1.890	28	.75	.0018 " .0007 "		5.5128 5.5123
						Timkin	8313	5.5118 5.5110	2.5591 2.5585	2.3175 2.3075	2.3175 2.3075			.0018 Tight .0007 "		5.5128 5.5123
						Norma Hoffman	R-365	5.5118 5.5112	2.6555 2.5587	1.2990 1.2970	1.2990 1.2970	14	.625	.0016 " .0005 "		5.5128 5.5123
C.W.	BW	135	16	620	4.75	Hyatt	T-312	5.1193 5.1181	2.5009 2.5000	2.0625	3.50	15	.75	.0015 Tight .0001 "	4.4390 4.4380	4.4400 4.4380
						Rollway	MDW313	5.5118 5.5111	2.5591 2.5585	1.2992	2.3125	20	.625	.0015 " .0004 "	4.4390 4.4370	"
						S.K.F.	22312	5.1181	2.5002 2.4996	1.8110	1.8110	28	.75	.0018 " .0007 "	4.4380 4.4360	"
						Timkin	8312	5.1181 5.1173	2.3622 2.3616	2.125	2.125			.0015 Tight .0003 "		"
						Norma Hoffman	R365-L	5.5118	2.5591	1.299	1.299	14	.625	.0015 " .0004 "		"
G.E.	MD104	145	20	725	6.00	Hyatt	MW215	5.1195 5.1181	3.0000 2.9990	2.625	2.625	24	.50		6.1265 6.1250	6.1250 6.1245
						Rollway	MDW315	6.2992	2.9528	1.4567	2.6875	21	.687	.0012 " .0003 "	4.5050 4.5010	4.5000 4.4995
						S.K.F.										
						Timkin										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 Tight .0003 "	4.5050 4.5010	4.5000 4.4995
W.E.M	MC40	176	20	600	5.00	Hyatt	"315	6.3011 6.2989	2.9542 2.9532	2.4375	2.4375	15	.9375		5.2520 5.2500	5.253 5.250
						Rollway	MS5315	6.2992	2.9528	2.6875	2.6875	14	.687		"	"
						S.K.F.	52315	6.2992	2.9528	2.1654	2.6875	30	.83	-.0015 -.0003	"	"
						Timkin	8315	6.2992	2.9528	2.6875				.0015 Tight .0003 "	"	"
						Norma Hoffman	WIR375-L	6.2992	2.9528	1.457	2.6875	14	.75		"	"
C.W.	CW	226	25	590	5.33	Hyatt	TW215	5.1195 5.1181	3.0000 3.0000	2.625	3.375	24	.50	.0015 Tight .0001 "	5.2510 5.2500	5.2520 5.2500
						Rollway	MDW316	6.6925 6.6917	3.1496 3.1490	1.5354	2.6875	21	.750	.0015 " .0004 "	5.2520 5.2500	"
						S.K.F.	22315	6.2992	3.0002 2.9997	2.165	2.165	38	.83	.0018 " .0007 "	5.2500 5.2480	"
						Timkin	8315	6.2992 6.2980	2.9528 2.9522	2.6875	2.6875			.0015 Tight .0003 "		"
						Norma Hoffman	R-380-L	6.6929	3.1496	1.5350	1.5350	15	.75	.0015 " .0004 "		"
G.E.	MD408	228	25	575	5.67	Hyatt	"316	6.6949 6.6926	3.1498 3.1489	2.5625	2.5425 2.5325	15	1	.0018 " .0004 "		6.6939 6.6934
						Rollway	MS-5316	6.6929 6.6917	3.1496 3.1490	2.6875	2.6875	15	.750	.0014 " .0003 "		6.6965 6.6945
						S.K.F.	22316	6.6925 6.6917	3.1496 3.1490	2.2830	2.2830	28	.94	.0017 " .0006 "		6.6939 6.6934
						Timkin	8316	6.6925 6.6917	3.1496 3.1490	2.6925 2.6825	2.6925 2.6825			.0017 Tight .0006 "		6.6939 6.6934
						Norma Hoffman	R-380	6.6925 6.6923	3.1498 3.1492	1.5350 1.5330	1.5350 1.5330	15	.75	.0015 " .0004 "		6.6939 6.6934
G.E.	MD104½	252	30	625	6.33	Hyatt	MW215	5.1195 5.1181	3.0000 2.9990	2.625	2.625	24	.50		6.1265 6.1250	6.1250 6.1245
						Rollway	MDW315	6.2992	2.9528	1.4567	2.6875	21	.687	.0012 " .0003 "	4.5050 4.5010	4.5000 4.4995
						S.K.F.										
						Timkin										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 Tight .0003 "	4.5050 4.5010	4.5000 4.4995
W.E.M	MC50	300	30	525	5.00	Hyatt	"315	6.3011 6.2989	2.9542 2.9532	2.4375	2.4375	15	.9375		5.252 5.250	5.2530 5.2500
						Rollway	MS5315	6.2992	2.9528	2.6875	2.6875	14	.687		"	"
						S.K.F.	52315	6.2992	2.9528	2.1654	2.6875	30	.83	-.0015 " -.0003 "	"	"
						Timkin	8315	6.2992	2.9528	2.6875				.0015 Tight .0003 "	"	"
						Norma Hoffman	WIR375-L	6.2992	2.9528	1.457	2.6875	14	.75		"	"
C.W.	DW	334	36	565	5.66	Hyatt	TW215	5.1195 5.1181	3.0009 3.0000	2.625	3.375	24	.50	.0015 Tight .0001 "	5.2510 5.2500	5.2520 5.2500
						Rollway	MDW316	6.6929 6.6917	3.1496 3.1490	1.5354	2.6875	21	.750	.0016 " .0004 "	5.2520 5.2500	"
						S.K.F.	22315	6.2992	3.0003 2.9997	2.1650		30	.83	.0018 " .0007 "	5.2500 5.2490	"
						Timkin	8315	6.2992 6.2980	2.9528 2.9522	2.6875				.0015 Tight .0003 "		"
						Norma Hoffman	R-380-L	6.6929	3.1496	1.535	1.535	15	.75	.0015 " .0004 "		"
G.E.	MD410	350	35	525	6.00	Hyatt	"317	7.0883 7.0866	3.3468 3.3453	2.75	2.7300 2.7200	16	1	.0017 " .0002 "		7.0877 7.0872
						Rollway	MS-5317	7.0866 7.0854	3.3465 3.3458	2.875	2.875	13	.875	.0015 " .0003 "		7.0902 7.0882
						S.K.F	22317	7.0866 7.0854	3.3465 3.3458	2.362	2.362	28	.98	.0017 " .0005 "		7.0877 7.0872
						Timkin	8317	7.0866 7.0854	3.3465 3.3458	2.8800 2.8700	2.8800 2.8700			.0017 Tight .0005 "		7.0877 7.0872
						Norma Hoffman	R-385	7.0866 7.0860	3.3467 3.3461	1.6140 1.6120	1.6140 1.6120	14	.875	.0014 " .0003 "		7.0877 7.0872
G.E.	MD105	383	40	550	5.66	Hyatt	MW215	5.1195 5.1181	3.0000 2.9990	2.625	2.625	24	.50		5.0010 5.0000	5.0020 4.9990
						Rollway	MDW315	6.2992 6.2980	2.9528 2.9523	1.4567	2.6875	21	.687	.0012 " .0003 "	5.0040 5.0010	5.0020 4.9990
						S.K.F.	22315	6.2992	2.9528	2.165	2.165	30	.83	.0012 " .0003 "	5.0040 5.0010	5.0020 4.9990
						Timkin										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 " .0003 "	5.0040 5.0010	5.0020 4.9990
C.W.	EW	450	47	550	6.00	Hyatt	TW220	7.0883 7.0866	4.0011 4.0000	3.25	4.375	22	.75	.0020 Tight .0004 "	6.5010 6.5000	6.502 6.500
						Rollway	MDW321			1.9291	3.4375	18	1.125	.0016 " .0006 "	6.5020 6.5000	"
						S.K.F.	22320	8.4646	4.0005 3.9998	2.874	2.874			.0022 " .0010 "	6.5000 6.4980	"
						Timkin	8320	8.4646 8.4634	3.9370 3.9363	3.250	3.250	28	1.22	.0017 Tight .0003 "		"
						Norma Hoffman	R405-L	8.8583	4.1339	1.9290	1.9290	16	1	.0016 " .0006 "		"

TABLE A-2

Motor Data						Bearing Data											
M'f'G	Frame	Torque	H.P.	R.P.M.	Min. Pin. Dia.	M'f'G	Series	A	B	C	D	Roller No	Roller Dia	Shaft Fit	Cart'g O.D.	Frame Bore
G.E.	MD412	525	50	500	6.33	Hyatt	"319	7.8758 7.8740	3.7405 3.7395	3.125	3.1050 3.0950	16	1.125	.0020 Tight .0005 "		7.8750 7.8745
						Rollway	MS5319	7.8741 7.8729	3.7402 3.7395	3.0625	3.0625	15	.875	.0015 " .0003 "		7.8776 7.8756
						S.K.F.	22319	7.8740 7.8728	3.7402 3.7395	2.6378	2.637	30	1.06	.0020 " .0008 "		7.8750 7.8745
						Timkin	8319	7.8741 7.8729	3.7402 3.7395	3.0675 3.0575	3.0675 3.0575			.0020 Tight .0008 "		7.8750 7.8745
						Norma Hoffman	R 395	7.8740 7.8734	3.7404 3.7398	1.7720 1.7700	1.7720 1.7700	16	.875	.0017 " .0006 "		7.8750 7.8745
W.E.M.	MC60	540	50	525	6.00	Hyatt	"319	7.8763 7.8736	3.7420 3.7408	3.125	3.125	16	1.125		6.2520 6.2500	6.2530 6.2500
						Rollway	MS5319	7.8740	3.7402	3.0625	3.0625	15	.875		"	"
						S.K.F.	52319	7.8740	3.7402	2.6378	3.0625	30	1.06	".0020 " .0006 "	"	"
						Timkin	8319	7.8740	3.7402	3.0625				.0017 "Tight .0003 "	"	"
						Norma Hoffman	WIR395L	7.8740	3.7402	1.772	3.0625	16	.875		"	"
C.W.	F.W.	660	66	525	6.40	Hyatt	TW220	7.0883 7.0866	4.0011 4.0000	3.25	4.375	22	.75	.0020 Tight .0004 "	6.5010 6.5000	6.5020 6.5000
						Rollway	MDW321	8.8583 8.8571	4.1339 4.1332	1.9291	3.4375	18	1.125	.0016 " .0006 "	6.5020 6.5000	"
						S.K.F.	22320	8.4646	4.0005 3.9998	2.874	2.874	28	1.22	.0022 " .0010 "	6.5000 6.4980	"
						Timkin	8320	8.4646 8.4634	3.9370 3.9363	3.25				.0017 Tight .0003 "		"
						Norma Hoffman	R405L	8.8583	4.1339	1.929	1.929	16	1	.0016 " .0006 "		"
G.E.	MD106	735	70	500	6.80	Hyatt	MW220	7.0883 7.0866	4.0000 3.9987	3.25	3.25	22	.75		6.2510 6.2500	6.2520 6.2490
						Rollway	MDW320	8.4646 8.4634	3.9370 3.9363	1.8504	3.25	20	1.00	.0017 " .0005 "	6.2540 6.2520	6.2520 6.2490
						S.K.F.	22320	8.4646	3.9370	2.874	2.874	28	1.22	.0017 " .0003 "	6.2540 6.2500	6.2520 6.2490
						Timkin	8320	8.4646 8.4634	3.9370 3.9363	3.250	3.250			.0017 Tight .0003 "	6.2510 6.2500	6.2520 6.2490
						Norma Hoffman	R400	8.4646	3.9370	1.850	1.850	14	1	.0017 " .0003 "	6.2510 6.2500	6.2520 6.2490
W.E.M	MC70	480	70	475	6.00	Hyatt	"319	7.8763 7.8736	3.7420 3.7408	3.125	3.125	16	1.125		6.252 6.250	6.253 6.250
						Rollway	MS5319	7.8740	3.7402	3.0625	3.0625	15	.875		"	"
						S.K.F.	52319	7.8740	3.7402	2.6378	3.0625	30	1.06	".0020 .0006	"	"
						Timkin	8319	7.8740	3.7402	3.1625				.0017 Tight .0003 "	"	"
						Norma Hoffman	WIR395L	7.8740	3.7402	1.772	3.0625	16	.875		"	"
G.E.	MD414	830	75	475	7.20	Hyatt	"322	9.4509 9.4489	4.3310 4.3295	3.750	3.7300 3.7200	15	1.375	.0021 " .0005 "		9.4502 9.4492
						Rollway	MS5322	9.4489 9.4477	4.3307 4.3300	3.625	3.625	15	1.125	.0016 " .0004 "		9.4524 9.4504
						S.K.F.	22322	9.4488 9.4476	4.3307 4.3300	3.150	3.150	28	1.38	.0020 " .0008 "		9.4502 9.4492
						Timkin	8322	9.4489 9.4477	4.3307 4.3300	3.6300 3.6200	3.6300 3.6200			.0020 Tight .0008 "		9.4502 9.4492
						Norma Hoffman	R410	9.4488 9.4482	4.3309 4.3303	1.9690 1.9670	1.9690 1.9670	14	1.125	.0017 " .0006 "		9.4502 9.4492
G.E.	MD107	895	85	500	7.60	Hyatt	TW222	7.8758 7.8740	4.5028 4.5014	3.50	4375	21	.875		7.0010 7.0000	7.0020 6.9990
						Rollway	MDW622S	9.4488	4.4993 4.4986	1.9685	3.625	20	1.125	.0016 " .0004 "	7.0040 7.0000	7.0020 6.9990
						S.K.F.										
						Timkin										
						Norma Hoffman										
C.W.	GW	940	90	500	8.00	Hyatt	TW222	7.8758 7.8740	4.5028 4.5014	3.500	4.375	21	.875	.0020 Tight .0004 "	7.001 7.000	7.002 7.000
						Rollway	MDW324	9.8426 9.8411	4.7244 4.7236	2.0473	3.75	21	1.125	.0016 " .0006 "	7.002 7.000	"
						S.K.F.	22322	9.4488	4.5007 4.5000	3.150	3.150	28	1.38	.0022 " .0010 "	7.000 6.998	"
						Timkin	8322	9.4489 9.4477	4.3307 4.3300	3.625	3.625			.0017 Tight .0003 "		"
						Norma Hoffman	R420L	10.2362	4.7244	2.165	2.165		1.125	.0016 " .0006 "		"
W.E.M	MC80	960	85	480	6.80	Hyatt	"322	9.4514 9.4484	4.3327 4.3313	3.75	3.75	15	1.375		7.059 7.000	7.003 7.000
						Rollway	MS5322	9.4489	4.3307	3.625	3.625	15	1.125		"	"
						S.K.F.	52322	9.4488	4.3307	3.1496	3.625	28	1.38	".0020 ".0006	"	"
						Timkin	8322	9.4488	4.3307	3.625				.0017 Tight .0003 "	"	"
						Norma Hoffman	WIR410L	9.4488	4.3307	1.969	3.625	14	1.125		"	"
W.E.M	MC90	1050	100	500	7.20	Hyatt	"324	10.2389 10.2356	4.7266 4.7251	4.125	4.125	16	1.375			7.378 7.375
						Rollway	MS5324	10.2362	4.7244	4.125	4.125	15	1.125			"
						S.K.F.	52324	10.2362	4.7244	3.3858	4.125	28	1.50	".0025 ".0009		"
						Timkin	8324	10.2362	4.7244	4.125				.0018 Tight .0003 "		"
						Norma Hoffman	WIR420L	10.2362	4.7244	2.1654	4.125	16	1.125			"
G.E.	MD108	1050	100	500	8.80	Hyatt	TMW226	8.4665 8.4646	5.0031 5.0016	3.875	4.875	27	.75		8.0010 8.0000	8.0020 7.9990
						Rollway	MDW626	10.2363 10.2351	4.9989 4.9982	2.1260	3.875	22	1.125	.0020 Tight .0008 "	8.0040 8.0020	8.0020 7.9990
						S.K.F.										
						Timkin										
						Norma Hoffman	RMS 23	10.000	5.000	2.000	2.000	16	1.125		8.0010 8.0000	8.0020 7.9990
G.E.	MD416	1140	100	460	8.00	Hyatt	"324	10.2383 10.2362	4.7247 4.7236	4.125	4.1050 4.0950	16	1.375	.0024 " .0008 "		10.2376 10.2366
						Rollway	MS5324	10.2363 10.2351	4.7244 4.7236	4.125	4.125	15	1.125	.0019 " .0005 "		10.2399 10.2379
						S.K.F.	22324	10.2362 10.2350	4.7244 4.7236	3.386	3.386	28	1.50	.0024 " .0011 "		10.2376 10.2366
						Timkin	8324	10.2362 10.2350	4.7244 4.7236	4.1300 4.1200	4.1300 4.1200			.0024 Tight .0011 "		10.2376 10.2366
						Norma Hoffman	R420	10.2362	4.7244	2.165	2.165		1.125			10.2376 10.2366

TABLE A-3

Motor Data / Bearing Data

Motor Data						Bearing Data											
M'f'G	Frame	Torque	H.P.	RPM	Min. Pin. Dia	M'f'G	Series	A	B	C	D	Roller No.	Roller Dia	Shaft Fit	Cart'g O.D.	Frame Bore
C.W.	H.W	1350	120	465	8.66	Hyatt	TMW226	8.4665 8.4646	5.0012 5.0000	3.875	4.875	27	.75	.0020 Tight .0004 "	8.0010 8.0000	8.0020 8.0000
						Rollway	MDW326	10.2363 10.2351	5.1181 5.1173	2.1260	3.875	22	1.125	.0021 " .0006 "	8.0020 8.0000	"
						S.K.F	22324	10.2363	5.0010 5.0002	3.386	3.386	28	1.50	.0020 " .0008 "	8.0000 7.9980	"
						Timkin	8324	10.2363 10.2351	4.7244 4.7236	4.125	4.125			.0019 Tight .0003 "		"
						Norma Hoffman	RMS23-L	10.000	5.000	2.000	2.000	16	1.125	.0021 " .0006 "		"
G.E.	MD418	1750	150	450	9.00	Hyatt	W226	9.0571 9.0551	5.1185 5.1173	4.250	4.2300 4.2200	21	1	.0024 " .0007 "		9.0566 9.0556
						Rollway	MS5326	11.0237 11.0221	5.1181 5.1171	4.375	4.375	15	1.250	.0025 " .0004 "		11.0279 11.0259
						S.K.F.	22326	11.0236 11.0224	5.1181 5.1173	3.6610	3.6610	28	1.61	.0024 " .0011 "		11.0279 11.0256
						Timkin	8326	11.0236 11.0220	5.1181 5.1171	4.3800 4.3700	4.3800 4.3800			.0026 Tight .0011 "		11.0279 11.0256
						Norma Hoffman	R430	11.0236	5.1181	2.3228	2.3228	15	1.25			
W.E.M	MC103	1990	180	475	8.80	Hyatt										
						Rollway	MS5326	11.0236	5.1181	4.375	4.375	15	1.250			
						S.K.F.	52326	11.0236	5.1181	3.6614	4.375	28	1.61	-.0025 -.0009		
						Timkin	8326	11.0236	5.1181	4.375				.0021" Tight .0003" "		
						Norma Hoffman	WIR430L	11.0236	5.1181	2.3228	4.375	15	1.25			
W.E.M	MC100	2100	150	370	8.00	Hyatt										
						Rollway	MS5326	11.0236	5.1181	4.375	4.375	15	1.250			8.2530 8.2500
						S.K.F.	52326	11.0236	5.1181	3.6614	4.375	28	1.61	-.0025 -.0009		"
						Timkin	8326	11.0236	5.1181	4.375				.0021" Tight .0003" "		"
						Norma Hoffman	WIR430L	11.0236	5.1181	2.3228	4.375	15	1.25			"
C.W.	I W	2140	175	430	10.00	Hyatt	W228	9.8451 9.8419	5.5144 5.5127	4.75	4.75	22	1.0625	.0025 Tight .0008 "		8.6270 8.6250
						Rollway	MDW328	10.4331 10.4316	5.5119 5.5111	2.2047	4.125	20	1.250	.0020 " .0007 "	8.6270 8.6250	"
						S.K.F										"
						Timkin	8328	11.8111 11.8095	5.5118 5.5108	4.500	4.500			.0022 Tight .0003 "		"
						Norma Hoffman	RMS23½L	11.000	5.500	2.000	2.000	17	1.125	.0015 " .0005 "		"
G.E.	MD109	2300	175	400	10.50	Hyatt	MW230	10.6320 10.6299	6.0000 5.9982	4.75	4.75	21	1.1875		9.5010 9.5000	9.5020 9.4990
						Rollway	MW31.004									
						S.K.F.										
						Timkin										
						Norma Hoffman	RMS24	12.000	6.000	2.250	2.250	16	1.25			
W.E.M	165	3300	275	42.5		Hyatt	D-228 D-232									
						Rollway										
						S.K.F.										
						Timkin										
						Norma Hoffman										
G.E.	MD3100½	3340	255	400	10.50	Hyatt	MW230	10.6320 10.6299	6.0000 5.9982	4.75	4.75	21	1.1875		9.5010 9.5000	9.5020 9.4990
						Rollway	MW31.004									
						S.K.F.										
						Timkin										
						Norma Hoffman	RMS24	12.000	6.000	2.250	2.250	16	1.25			
G.E.	MD5420	3350	275	375		Hyatt	W230	10.6320 10.6299	5.9055 5.9046	4.750	4.7300 4.7200	21	1.1875	.0026 Tight .0008 "		10.6314 10.6304
						Rollway	MS5330	12.5984 12.5968	5.9055 5.9045	4.875	4.875	15	1.50	.0026 " .0006 "		12.6027 12.6007
						S.K.F.	22330	12.5984 12.5972	5.9055 5.9047	4.252	4.252	28	1.85	.0025 " .0012 "		12.6027 12.6004
						Timkin	8330	12.5985 12.5969	5.9055 5.9045	4.8800 4.8700	4.8800 4.8700			.0027 Tight .0012 "		12.6027 12.6004
						Norma Hoffman										
G.E.	MD3110	4430	295	350		Hyatt										
						Rollway										
						S.K.F.										
						Timkin										
						Norma Hoffman										

LEGEND:-

DATA ON BEARING DIMENSIONS, FITS, TOLERANCE, ETC., OBTAINED FROM THE FOLLOWING PUBLICATIONS. SUPPLEMENTED THRU CORRESPONDENCE WITH THE VARIOUS BEARING MANUFACTURERS

Manufacturer	Publication	Cat. No	Data
1-HYATT ROLLER BEARING Co.	DIMENSION & LOAD BULLETIN	FORM 1559	SEPT. 1928
2-ROLLWAY BEARING Co.	ENGINEERING DATA SHEETS		1928
3-SKF INDUSTRIES INC.	ENGINEERING DATA SHEETS		JAN. 1928
4-TIMKIN ROLLER BEARING Co.	ENGINEERING DATA SHEETS	CAT.# 917	1927
5-NORMA HOFFMAN BEARING Co.	ENGINEERING DATA SHEETS		
6-W.E. & Mfg. Co.	ENGINEERING BLUE PRINTS		
7- G.E. Co.	ENGINEERING BLUE PRINTS		

TABLE A-4

Roller Bearing Shaft Fits

S.A.E. St'd.					Westinghse Adaption				Hyatt Adaption			
Bearing No	Bearing Bore	Shaft Dia.	Fit Max.	Fit Min.	Bearing Bore	Shaft Dia.	Fit Max.	Fit Min.	Bearing Bore	Shaft Dia.	Fit Max.	Fit Min.
310	1.9685 1.9680	1.9686 1.9690	-.0010	-.0001	1.9685 1.9680	1.9685 1.9690	-.0010	+.0000	1.9687 1.9679	1.9688 1.9695	-.0016	-.0001
313	2.5591 2.5585	2.5593 2.5598	-.0013	-.0002	2.5591 2.5585	2.5590 2.5595	-.0010	+.0001	2.5593 2.5584	2.5594 2.5603	-.0019	-.0001
315	2.9528 2.9522	2.9530 2.9535	-.0013	-.0002	2.9528 2.9522	2.9530 2.9535	-.0013	-.0002	2.9530 2.9521	2.9532 2.9542	-.0021	-.0002
319	3.7402 3.7395	3.7405 3.7410	-.0015	-.0003	3.7402 3.7395	3.7405 3.7410	-.0015	-.0003	3.7404 3.7394	3.7408 3.7420	-.0026	-.0004
322	4.3307 4.3300	4.3311 4.3316	-.0015	-.0003	4.3307 4.3300	4.3310 4.3315	-.0015	-.0003	4.3309 4.3298	4.3313 4.3327	-.0029	-.0004
324	4.7244 4.7236	4.7249 4.7255	-.0019	-.0006	4.7244 4.7236	4.7250 4.7255	-.0019	-.0006	4.7246 4.7235	4.7251 4.7266	-.0031	-.0005
326	5.1181 5.1171	5.1187 5.1193	-.0017	-.0004	5.1181 5.1173	5.1185 5.1190	-.0017	-.0004				

Roller Bearing Cartridge Fits

	Bearing O.D.	Cartridge Bore	Fit Max.	Fit Min.	Bearing O.D.	Cartridge Bore	Fit Max.	Fit Min.	Bearing O.D.	Cartridge Bore	Fit Max.	Fit Min.
310	4.3307 4.3299	4.3319 4.3339	+.0040	+.0012	4.3307 4.3299	4.3309 4.3322	+.0023	+.0002	4.3320 4.3307	4.3306 4.3322	-.0015	+.0014
313	5.5118 5.5110	5.5130 5.5150	+.0040	+.0012	5.5118 5.5110	5.5120 5.5133	+.0023	+.0002	5.5133 5.5118	5.5116 5.5135	-.0017	+.0017
315	6.2992 6.2980	6.3008 6.3028	+.0046	+.0016	6.2992 6.2980	6.2995 6.3010	+.0030	+.0003	6.3008 6.2992	6.2989 6.3011	-.0019	+.0019
319	7.8741 7.8729	7.8756 7.8776	+.0047	+.0015	7.8741 7.8729	7.8745 7.8762	+.0033	+.0004	7.8758 7.8740	7.8736 7.8763	-.0023	+.0022
322	9.4489 9.4477	9.4504 9.4524	+.0047	+.0015	9.4489 9.4477	9.4493 9.4510	+.0033	+.0004	9.4509 9.4489	9.4484 9.4514	-.0025	+.0025
324	10.2363 10.2351	10.2379 10.2399	+.0048	+.0016	10.2362 10.2350	10.2367 10.2385	+.0035	+.0005	10.2383 10.2362	10.2356 10.2389	-.0027	+.0027
326	11.0237 11.0221	11.0259 11.0279	+.0058	+.0022	11.0236 11.0224	11.0242 11.0260	+.0036	+.0006				

NOTE:– Negative Implies Interfence Or "Press Fit."
Positive Implies Looseness Or "Slip Fit."

Table B

Crocker Wheeler Shaft Fits							Cartridge Fits			
Motor Frame	Bearing Mf'g.	Bearing No.	Bearing Bore	Shaft Dia.	Fits Max.	Fits Min.	Frame Bore	Cartridge Dia.	Fits Max.	Fits Min.
AW	Hyatt	T-310	2.0008 2.0000	2.0015 2.0010	-.0015	-.0002	3.9400 3.9380	3.9390 3.9380	+.0020	-.0010
	Rollway	MDW-311	2.1654 2.1649	2.1663 2.1660	-.0014	-.0006	3.9400 3.9380	3.9400 3.9380	±.0020	-.0020
	S.K.F.	22310	2.0005 2.0000	2.0015 2.0010	-.0015	-.0005	3.9400 3.9380	3.9380 3.9360	±.0040	-.0000
	Hoffman	R-355-L	2.1654 2.1649	2.1663 2.1660	-.0014	-.0006				
	Timkin									
BW	Hyatt	T-312	2.5009 2.5000	2.5015 2.5010	-.0015	-.0001	4.4400 4.4380	3.9390 3.9380	±.0020	-.0010
	Rollway	MDW-313	2.5591 2.5585	2.5610 2.5600	-.0025	-.0009	4.4400 4.4380	3.9400 3.9380	±.0020	-.0020
	S.K.F.	22312	2.5002 2.4996	2.5015 2.5010	-.0019	-.0008	4.4400 4.4380	3.9380 3.9360	±.0040	-.0000
	Hoffman	R-365-L	2.5591 2.5585	2.5610 2.5600	-.0025	-.0009				
	Timkin									
CW DW	Hyatt	TW-215	3.0000 3.0000	3.0015 3.0010	-.0015	-.0010	5.2520 5.2500	5.2510 5.2500	±.0020	-.0010
	Rollway	MDW-316	3.1496 3.1490	3.1505 3.1500	-.0015	-.0004	5.2520 5.2500	5.2520 5.2500	±.0020	-.0020
	S.K.F.	22315	3.0003 2.9997	3.0015 3.0010	-.0018	-.0007	5.2520 5.2500	5.2500 5.2480	±.0040	-.0000
	Hoffman	R-380-L	3.1496 3.1490	3.1505 3.1500	-.0015	-.0004				
	Timkin									
EW FW	Hyatt	TW-220	4.0011 4.0000	4.0020 4.0015	-.0020	-.0004	6.5020 6.5000	6.5010 6.5000	±.0020	-.0010
	Rollway	MDW-321	4.1339 4.1332	4.1350 4.1345	-.0018	-.0006	6.5020 6.5000	6.5020 6.5000	±.0020	-.0020
	S.K.F.	22320	4.0005 3.9998	4.0020 4.0015	-.0022	-.0010	6.5020 6.5000	6.5000 6.4980	±.0040	-.0000
	Hoffman	R-405-L	4.1339 4.1332	4.1350 4.1345	-.0018	-.0006				
	Timkin									
GW	Hyatt	TW-222	4.5028 4.5014	4.5020 4.5015	-.0006	+.0013	7.0020 7.0000	7.0010 7.0000	±.0020	-.0010
	Rollway	MDW-324	4.7244 4.7236	4.7255 4.7250	-.0019	-.0006	7.0020 7.0000	7.0020 7.0000	±.0020	-.0020
	S.K.F.	22322	4.5007 4.5000	4.5020 4.5015	-.0020	-.0008	7.0020 7.0000	7.0000 6.9980	±.0040	-.0000
	Hoffman	R-420-L	4.7244 4.7236	4.7255 4.7250	-.0019	-.0006				
	Timkin									
HW	Hyatt	TMW-226	5.0012 5.0000	5.0025 5.0020	-.0025	-.0008	8.0020 8.0000	8.0010 8.0000	±.0020	-.0010
	Rollway	MDW-326	5.1181 5.1172	5.1200 5.1190	-.0028	-.0009	8.0020 8.0000	8.0020 8.0000	±.0020	-.0020
	S.K.F.	22324	5.0010 5.0002	5.0025 5.0020	-.0023	-.0010	8.0020 8.0000	8.0000 7.9980	±.0040	-.0000
	Hoffman	RMS-23-L	5.0000 4.9991	5.0012 5.0007	-.0021	-.0007				
	Timkin									
IW	Hyatt	W-226	5.5144 5.5127	5.5135 5.5130	-.0008	+.0014				
	Rollway	MDW-328	5.5119 5.5111	5.5130 5.5125	-.0019	-.0006	8.6270 8.6250	8.6270 8.6250	±.0020	-.0020
	S.K.F.									
	Hoffman	RMS-23½-L	5.5000 5.5017	5.5032 5.5007	-.0015	-.0007				
	Timkin									

NOTE:- Negative Implies Interfence Or "Press Fit"
Positive Implies Looseness Or "Slip Fit"

Table B-1

The Application of Roller Bearings to General Electric Company MD Motors

By C. W. LANGE*

The information in this paper covers the application of various makes of roller bearings to the old MD-100 and the new MD-400 lines of General Electric Mill Type Motors, based on recommendations of the roller bearing manufacturers, and on the A.I.&S.E.E. standardization of mill motors for sizes MD-403 to MD-414 inclusive of the new line of mill motors. As the MD-100 line of motors is now obsolescent, being superseded by the new MD-400 line, only those bearings which have actually been applied up to the present time are listed for the MD-100 motors, and no attempt has been made to cover additional possible combinations of bearing makes and sizes.

MD-100 MOTORS

The motor sizes, roller bearing sizes of various makes, assembly drawings with necessary dimensions, parts drawings, and drawings showing dimensions and changes necessary in the armature bearing housings are listed on drawing P-747894. Where roller bearings of a particular make or size have not been applied, this drawing so indicates.

Similar information covering actual applications of roller bearings to the back axles of MD-100 motors is shown on drawing P-747898.

For frames MD-101 to MD-104½ inclusive, special drawings showing the necessary changes in armature bearing housings have been made up, these drawings being listed on P-747894. For frames MD-105 to MD-109 inclusive, the necessary changes in armature bearing housings for Hyatt bearings are shown on drawing P-3647874, and for other makes on the corresponding assembly drawings.

For frames MD-101 to MD-104½ inclusive, no assembly or parts drawings have been made by the General Electric Co. for Rollway or SKF bearings, the necessary parts drawings for those sizes which have been applied being furnished by the roller bearing manufacturers. The known roller bearing manufacturers' drawing numbers are however, shown on G. E. drawing P-747849.

For frames MD-105 to MD-109 inclusive, assembly and parts drawings have been made up by the General Electric Co. for Rollway bearings but not for SKF bearings, the SKF drawing number, if known, being shown on G. E. drawing P-747849.

In the case of Hyatt roller bearings, the cartridge and cap are manufactured by the General Electric Company, whereas in the case of Rollway and SKF roller bearings the cartridge and cap as well as the bearings are manufactured by the roller bearing manufacturer.

The following detailed explanation for the different MD-100 frame sizes and makes of roller bearings, although partly a recapitulation of the information shown on the various assembly and parts drawings, is also an amplification of such information, and is intended as an aid in the interpretation of such drawings.

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MD-101
ARMATURE BEARINGS

Standard journal 1-¾" dia.
Standard housing bore 3" dia.

Rollway Bearings

Parts per Rollway Bearing Co. drawing MM4200.
Adaptation per G. E. Co. drawing P-3723524.

The changes required to apply Rollway MDW-309 bearings consist of the following:

(1) Special oversize shaft and thrust collars.

(2) Suitable thrust collars.

(3) Bearing housing rebored to 3-⅜" dia. full length, and the central portion bored to 5" dia. beginning 1-⅜" from outer end of housing and extending 2" toward center of motor. A small amount of chipping is also necessary at the central portion.

(4) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Company, Inc., Syracuse, N. Y.

Hyatt Bearings

Parts per G. E. Co. drawing M-3718434 G1
Assembly per G. E. Co. drawing T-3707231
Adaptation per G. E. Co. drawing P-3723522

The changes required to apply Hyatt W-209 roller bearings consist of the following:

(1) Special oversize shaft.

(2) Special magnet frame with additional stock on bearing housings to permit boring to 4-½" dia. Changes are such as to make it impracticable to change old frame.

(3) Bearings, cartridges, and spacers are supplied by the General Electric Co.

Back Axle Bearings

No back axle roller bearings have been applied to this size of motor.

MD-102
ARMATURE BEARINGS

Standard journal 2-¼" dia.
Standard housing bore 3-½" dia.

Rollway Bearings

Parts per Rollway Bearing Co. drawing MM2200.
Adaptation per G. E. drawing P-3723524.

The changes required to apply Rollway MDW-312 bearings consist of the following:

MD-100-230 VOLT MOTORS

60 MIN. 75°C				STD. PINION			HYATT ROLLER BEARING				ROLLWAY ROLLER BEARING				S.K.F. ROLLER BEARING			TIMKEN ROLLER BEARING	HOFFMAN ROLLER BEARING
FRAME SIZE	H.P.	R.P.M.	TORQUE IN LBS AT 1 FT. RADIUS	NO. OF TEETH	D.P.	FACE	SIZE	ASSEMBLY DRAWING	PARTS DRAWING	DRAWING SHOWING CHANGES NECESSARY TO CONVERT MOTORS TO ROLLER BEARINGS	SIZE	ASSEMBLY DRAWING	BEARING & CARTRIDGE ORDERED FROM ROLLWAY BEARING CO. SYRACUSE, N.Y. PER DRAWING	DRAWING SHOWING CHANGES NECESSARY TO CONVERT MOTORS TO ROLLER BEARINGS	SIZE	BEARING & CARTRIDGE ORDERED FROM SKF CO. 165 BROADWAY, N.Y. PER DRAWING	DRAWING SHOWING CHANGES NECESSARY TO CONVERT MOTORS TO ROLLER BEARINGS		
MD 101	4	975	21.5	16	4	2½	W-209	T-3707231	M-3718434G-1	P-3723522	MDW-309	NONE	MM-4200	R3723524					
MD 102	9	875	54	19	4	3½	MW-211	T-3707231	K-3707387 PTS 2,3,4,5,6,7&8	P-3723522	MDW-312	NONE	MM-2200	P-3723524	22312	Y-426	P-3723523		
MD 103	13	800	85.5	21	4	4	TW-213	T-3707231	P-3723826G-1	P-3723522	MDW-313	NONE	MM-4100-A	P-3723524					
MD 104	20	725	145	24	4	4½	MW-215	T-3707231	K-3706791 PTS 2,3,4,5,6,7&8	P-3723522	MDW-315	NONE	MM-1600	P-3723524				NEVER DEVELOPED	
MD 104½	30	625	252	19	3	4½	MW-215	T-3707231	K-3710657 PTS 2,3,4,5,6,7&8	P-3723522	MDW-315	NONE	MM-1600	P-3723524					
MD 105	40	550	383	17	3	4½	MW-215	T-2857478	T-2857477G-1	P-3647874	MDW-315	P-2878343	P-2878343G-1						
MD 106	70	500	735	17	2½	5	MW-220	T-3632903	T-3632904G-1	P-3647874	MDW-320	T-2857409	T-2857409G-1		22320	Y-523			NEVER DEVELOPED
MD 107	85	500	895	19	2½	5½	TW-222	TT-1853832	W-3638613G-1	P-3647874	MDW-622.5	T-2857453	T-2857453G-1						
MD 108	100	500	1050	22	2½	6	TMW-226	W-2859759	T-3632936G-1	P-3647874	MDW-626	T-3632961	T-3632961G-1						
MD 109	175	400	2300	21	2	7	W-230 (SPECIAL WORK)	TT-3634009	W-2859765G-1	P-3647874	CAT. MW-3004	T-3635970	W-3674552G-1						

NOTE:
HYATT DESIGNATION "MW" INDICATES A MODIFIED "W" BEARING WITH ENLARGED I.D. OF INNER RACE

HYATT DESIGNATION "TW" INDICATES A MODIFIED "W" BEARING WITH ENLARGED OR REDUCED I.D. AND INCREASED LENGTH OF INNER RACE.

HYATT DESIGNATION "TMW" INDICATES A MODIFIED "W" BEARING WITH REDUCED I.D. AND O.D. OF INNER RACE, INCREASED LENGTH OF INNER RACE, REDUCED LENGTH OF OUTER RACE, SPECIAL ROLLERS

RATING & CHANGE DATA

ON MD 100 MOTORS

Drawing Number P 74789A

General Electric Company
Erie Works

(1) Complete new armature, since the required shaft is oversize and spider bore is oversize. Special thrust collars are used.

(2) Bearing housings on frame re-bored to 4" dia. full length, and the central portion bored to 6-⅜" dia. beginning 1-17/32" from outer end of housing and extending 2-7/16" toward center of motor.

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Hyatt Bearings

Parts per G. E. drawing K-3707387, parts 2 to 8 inclusive.

Assembly per G. E. drawing T-3707231.

Adaptation per G. E. drawing P-3723522.

The changes required to apply Hyatt MW-211 roller bearings consist of the following:

(1) Add dowel pins ¼" dia. x 11/32" long at each end of shaft, 4-17/32" from the face of thrust collar.

(2) Re-bore bearing housings to 4-13/16" dia. from outer end to oil ring space. The bore at inner end of housing remains standard.

(3) Bearings, cartridges, and spacers are supplied by the General Electric Co.

SKF Bearings

Parts per SKF drawing Y-426.

Adaptation per G. E. Co. drawing P-3723523.

The changes necessary to apply SKF No. 22312 roller bearings consist of:

(1) Complete new armature, since the required shaft is oversize and the spider bore is oversize. Special thrust collars are used.

(2) Bearing housings re-bored to 4" dia. full length, and the central portion bored to 6-⅛" dia. beginning 4-1/16" from outer end and extending approximately 2-⅝" toward the outer end of housing. Also 5-¼" dia. bore 11/16" from outer end of housing (7/16" radius cutter) and taper 30° to the 6-⅛" bore.

(3) Bearings, cartridges, and spacers are manufactured by the SKF industries.

Back Axle Bearings

The only roller bearings applied to the back axle of this size motor are Hyatt MW-215.

The changes necessary are:

(1) Magnet frame and back axle bearing caps of special construction, with special machining of back axle bearing housings, as shown on drawing P-747898. No cartridges used.

(2) Magnet frame, bearing caps, bearings and retaining plates furnished by the General Electric Co.

MD-103 ARMATURE BEARINGS

Standard journal 2-½" dia.
Standard housing bore 3-¾" dia.

Rollway Bearings

Parts per Rollway Bearing Co. drawing MM-4100-A.

Adaptation per G. E. Co. drawing P-3723524.

The changes required to apply Rollway MDW-313 bearings consist of the following:

(1) Complete new armature, since the required shaft is oversize and the spider bore is oversize. Special thrust collars are used.

(2) Bearing housings on frame re-bored to 4-¾" dia. full length, and the central portion bored to 6-½" dia., beginning 2" from outer end of housing and extending 2-⅜" toward center of motor, ¼" chamfer at corners.

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Hyatt Bearings

Parts per G. E. drawing P-3723826 G1.

Assembly per G. E. drawing T-3707231.

Adaptation per G. E. drawing P-3723522.

The changes required to apply Hyatt TW-213 roller bearings consist of the following:

(1) Special oversize shaft.

(2) Re-bore bearing housings to 5-¾" dia. from outer end to the oil ring space.

(3 Bearings, cartridges, and spacers are supplied by the General Electric Co.

Back Axle Bearings

The only roller bearings applied to the back axle of this size motor are Hyatt TW-213.

The changes necessary are:

(1) Magnet frame and back axle bearing caps of special construction, with special machining of back axle bearing housings, as shown on drawing P-747898. No cartridges used.

(2) Magnet frame, bearing caps, bearings and retaining plates furnished by the General Electric Co.

MD-104, MD-104½ AND MDS-104½ ARMATURE BEARINGS

Standard journal 3" dia.
Standard housing bore 4-½" dia.

Rollway Bearings

Parts per Rollway Bearing Co. drawing MM-1600.

Adaptation per G. E. Co. drawing P-3723524.

The changes required to apply Rollway MDW-315 bearings consist of the following:

(1) Re-machine shaft at journals to reduce diameter from 3" to 2.9523" + .0003"-.0000".

(2) Re-bore bearing housings on magnet frame at central portion to 7-9/16" dia. beginning 2" from outer end of housing and extending 2-⅝" towards center of motor.

(3) Bearings, cartridges and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Hyatt Bearings

Parts per G. E. drawing K-3706791, parts 2 to 8 inclusive for MD-104.

Parts per G. E. drawing K-3710657, parts 2 to 8 inclusive for MD-104½ and MDS-104½.

Assembly per G. E. drawing P-3707231.

Adaptation per G. E. drawing P-3723522.

The changes required to apply Hyatt MW-215 roller bearings consist of the following:

(1) Add 3/8" dia. x 15/32" long dowel pin at each end of shaft 6-3/32" from face of thrust collar.

(2) Re-bore bearing housings on magnet frame to 6-1/8" dia. from outer end to oil ring space. The diameter at inner end is left standard.

(3) Bearings, cartridges, and spacers are supplied by the General Electric Co.

Back Axle Bearings

No back axle roller bearings have been applied to this size of motor.

MDS-102 TO MDS-104 INCLUSIVE

These motors use bearing linings split vertically, and the bearing housings are smaller than on the corresponding MD motors. Consequently the roller bearings and parts for MD motors are not applicable to the corresponding MDS motors for these sizes.

For frames MD-105 to MD-109 inclusive, and MDS-105 to MDS-109 inclusive, the explanation covering the application of Hyatt armature bearings is the same for all sizes and this explanation is therefore given under the general heading of "Hyatt Roller Bearings." In the case of Rollway and SKF armature bearings, and Hyatt back axle bearings, explanations are given for each frame size.

HYATT ROLLER BEARINGS FOR ARMATURE

MD-105 to MD-109 inclusive, and MDS-105 to MDS-109 inclusive

Frame Size	Roller Bearing	G.E. Parts Drawing	G.E. Assembly Drawing	Adapt. per G.E. Draw.
MD & MDS-105	MW-215	T-2857477 G1	T-2857478	P-3647874
MD & MDS-106	MW-220	T-3632904 G1	T-3632903	P-3647874
MD & MDS-107	TW-222	W-3638613 G1	TT-1853832	P-3647874
MD & MDS-108	TMW-226	T-3632936 G1	W-2859759	P-3647874
MD & MDS-109	(W-230) (Spec. I.D.)	W-2859765 G1	TT-3634009	P-3647874

The following changes or precautions are necessary:

(1) Standard shaft and bearing housing are used, but it is necessary to check the shaft diameter and housing bore to determine whether these dimensions are within the specified limits.

Add dowel pins at each end of shaft, located from the face of thrust collar, as shown on drawing P-3647874.

(2) Whenever the upper half of bearing housing has a cast partition for waste packing, this partition must be removed.

Any irregularities on inner walls of bottom half of bearing housing must be chipped off to obtain a width of chamber equal to the dimensions shown.

Check the dimension from shoulder for cartridge to inside of outer wall of housing, and remove metal if necessary to obtain the specified diameter required for clearance. Similarly, metal is to be removed from the wall at inner end of the bearing housing if thickness of wall is in excess of the dimension shown.

(3) Bearings, cartridges, and spacers are supplied by the General Electric Co.

MD AND MDS-105 ARMATURE BEARINGS

Rollway Bearings

Parts per G. E. drawing P-2878343 G1.

Assembly and Adaptation per G. E. drawing P-2878343.

The changes required for the application of Rollway MDW-315 bearings are as follows:

(1) Shaft re-machined, measured from face of thrust collar, to dimensions shown.

(2) The bore at ends of bearing housing is standard, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

Finish inside wall at back of bottom half of housing to dimensions shown.

Bore out the oil well to 7-7/8" dia. for its entire length of 3-7/8".

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Back Axle Bearings

The only roller bearings applied to the back axle of this size motor are Hyatt MW-220.

The changes necessary are:

(1) Magnet frame and back axle bearing caps of special construction, with special machining of back axle bearing housings, as shown on drawing P-747898. No cartridges used.

(2) Magnet frame, bearing caps, bearings and retaining plates furnished by the General Electric Co.

MD AND MDS-106 ARMATURE BEARINGS

Rollway Bearings

Parts per G. E. drawing T-2857409 G1.

Assembly and Adaptation per G. E. drawing T-2857409.

The changes required for the application of Rollway MDW-320 bearings are as follows:

(1) Shaft re-machined, measured from face of thrust collar, to dimensions shown.

(2) The bore at ends of bearing housing is standard, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

Finish inside wall at back of bottom half of housing to dimensions shown, and remove irregularities from inside of front wall.

Bore out the oil well to 10-1/8" dia. for its entire length of 5-1/4".

(3) Bearings, cartridges and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

SKF Bearings

Parts per SKF drawing Y-523.

The changes required for the application of SKF No. 22320 bearings are:

(1) Shaft re-machined, measured from face of thrust collar to taper on shaft, to dimensions shown.

(2) The bore at ends of bearing housing is standard, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

Bore out the oil well to 10-⅛" dia. for its entire length of 5-¼".

(3) Bearings, cartridges and spacers are manufactured by the SKF Industries, 165 Broadway, New York City.

Back Axle Bearings

The only roller bearings applied to the back axle of this size motor are Hyatt TMW-226.

The changes necessary are:

(1) Magnet frame and back axle bearing caps of special construction, with special machining of back axle bearing housings, as shown on drawing P-747898. No cartridges used.

(2) Magnet frame, bearing caps, bearings and retaining plates furnished by the General Electric Co.

MD AND MDS-107 ARMATURE BEARINGS

Rollway Bearings

Parts per G. E. drawing T-2857453 G1.

Assembly and Adaptation per G. E. drawing T-2857453.

The changes required for the application of Rollway MDW-622.5 bearings are as follows:

(1) Standard shaft diameter used, but this must be checked to determine if dimension is within specified limits.

(2) The bore at ends of bearing housings is standard, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

Finish inside wall at back of bottom half of housing to dimensions shown, and remove irregularities from inside of front wall.

Bore out the oil well to 11-¼" dia. for a distance of 5⅛" measured from inside of front wall.

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Back Axle Bearings

No back axle roller bearings have been applied to this size of motor.

MD AND MDS-108 ARMATURE BEARINGS

Rollway Bearings

Parts per G.E. drawing T-3632961 G1.

Assembly and Adaptation per G.E. drawing T-3632961.

The changes required for the application of Rollway MDW-626 bearings are as follows:

(1) Standard shaft diameter used, but this must be checked to determine if dimension is within specified limits.

(2) The bore at ends of bearing housings is standard, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

Finish inside wall at back of bottom half of housing to dimensions shown, and remove irregularities from inside of front wall.

Bore out the oil well to 12-¼" dia. for its entire length of 6-½".

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Back Axle Bearings

No back axle roller bearings have been applied to this size of motor.

MD AND MDS-109 ARMATURE BEARINGS

Rollway Bearings

Parts per G.E. drawing M-3674552 G1.

Assembly and Adaptation per G.E. drawing T-3635970.

The changes required for the application of Rollway MW-31004 bearings are as follows:

(1) Standard shaft diameter used, but this must be checked to determine if dimension is within specified limits.

(2) Standard bearing housing and housing bore are used, but must be checked to determine if dimensions are within specified limits. If upper half of bearing housing has partition for waste-packing, it is necessary to remove this partition.

(3) Bearings, cartridges, and spacers are manufactured by the Rollway Bearing Co., Inc., Syracuse, N. Y.

Back Axle Bearings

No back axle roller bearings have been applied to this size of motor.

MD-400 MOTORS

The application of various makes of roller bearings to the armatures and back axles of the new MD-400 motors is covered by tabulated drawing PP-747897, which shows the bearing sizes, parts required, and fits for outer and inner races.

The bearing sizes for frames MD-403 to MD-414 inclusive, for both armature shafts and back axles, are those standardized by the A.I.&S.E.E. for mill type motors.

For frames MD-418 and MD-420 no provision has been made for the wide 200 series roller bearings on the back axles, because of the excessive size. Consideration has been given to the possible use of wide 100 series roller bearings in tandem, but as there has been no demand for back axle roller bearings for these sizes, oil ring back axle bearings are considered standard.

For frames MD-418 and MD-420, wide 200 series bearings are standard for armature, and new frame heads are necessary if 300 series bearings are used.

For frames MD-402 to MD-416 inclusive 300

series roller bearings are standard for armature. Wide 200 series bearings are standard for back axles, being optional with oil ring bearings, the roller bearing cartridges being interchangeable with the oil ring bearings.

Also for frames MD-402 to MD-416 inclusive the same armature shafts and back axles are used interchangeably for all makes of roller bearings.

The same thrust plates are used with Hyatt-300 and Rollway D-300 bearings. No thrust plates are used with SKF-22300 and Timken 8300 bearings, but rectangular retaining shrink rings are used with SKF-22300 bearings. Combined shrink rings and thrust plates are used with Norma-Hoffman bearings

The same frame heads without change are used for Hyatt 300, SKF-22300, Rollway D-300, and Norma-Hoffman bearings, but filler rings as shown are required for SKF and Norma-Hoffmann bearings. The same bearing cap is used for Hyatt-300 and SKF-22300 of same sizes, Rollway D-309 and D-311 bearings, but bearing caps for remaining Rollway D-300 have different depth of rabbet because of different race widths, and Norma-Hoffmann bearing caps (although rabbet is the same as for Hyatt-300 and SKF-22300) have the stop machined off somewhat to prevent interference with roller cage.

For Timken 8300 and Rollway MS-5300 self-contained bearings the frame heads and bearing caps are different than for other makes in order to permit lateral motion in the housing due to expansion of shaft and to take the thrust at inner end of housing. The bearing caps are identical for these two makes and the frame heads would be identical except that the housing bores recommended by the two manufacturers are different.

The Hyatt-300 and Rollway D-300 permit of the quickest disassembly since the frame head with roller assembly and outer race can be removed by merely pulling the head off the shaft in the same manner as for a sleeve bearing, without removing the inner race from shaft. These two makes and the Norma-Hoffmann bearings require additional thrust plates which take ordinary thrust loads. The Rollway MS-5300 bearings take ordinary thrust loads without thrust plates. The SKF-22300 and Timken 8300 bearings take heavy thrust loads without thrust plates, and therefore in special cases where additional thrust loads are to be imposed, they may be preferable.

Copies of reference drawings can be obtained upon request from the General Electric Company.

Economizers

By W. F. KEENAN, JR.*

Economizers are used extensively in central station and industrial power plants. The principal designs now offered are of the horizontal steel tube type arranged for counter current flow to obtain maximum mean temperature difference between gas and water. The tubes are in horizontal rows one above the other, and are arranged in vertical sections side by side each section including one tube in each horizontal row. The tubes in each section are connected in series between inlet and outlet manifolds. This arrangement provides several separate paths for flow of water through economizer in each of which contraction and expansion can be taken up freely, and independently of contraction and expansion in adjacent sections. Tubes are assembled in a casing through which gases flow vertically—up or down—in a direction opposite to the flow of water. Thus hot entering gases contact with tubes carrying hot water leaving economizer and outlet water temperatures are often in excess of outlet gas temperatures.

This type of economizer is almost invariably installed without any flue for by-passing gas around it and in connection with one boiler only as an integral part of a complete and self-contained steam generating unit. Compared to the one time practice of having one economizer serve several boilers this reduces costs, saves space and practically eliminates losses due to radiation and air infiltration between boiler and economizer and through by-pass flues and dampers which are rarely if ever tight.

In old style vertical cast iron tube economizers the average rate of heat transfer was between 1.5 and 2.0 Btu per hour per sq. ft. per degree mean temperature difference. In modern horizontal steel tube economizers heat transfer rates are rarely less than 5.0. The principal reason for this is that economizers are now designed not for minimum possible gas velocities and draft losses but for high gas velocities and relatively high draft losses in order to realize the net economies that result from the use of such velocities and draft losses. On the part of some engineers there remains a prejudice in favor of lowest possible draft losses. Probably one of the reasons for this is that it is not generally realized that the added cost of such additional draft is less than the corresponding savings in costs of economizers or in improved economizer performances.

Figure I shows water temperature rise in economizer that — for typical conditions assumed — will provide necessary heat for generation of power for induced draft fans. It will be noted that this amounts to 2.4 degrees per inch of draft loss, if gas temperature at fan is 500 degrees, and only 1.9 degrees, if gas temperature at fan is 300 degrees, a more nearly normal value. It is, therefore, proper to state that in an ordinary installation no operating expense charge for power to carry gases through economizer should be made if for each inch of draft loss through economizer 2″ water temperature rise is deducted from the savings credited to economizer.

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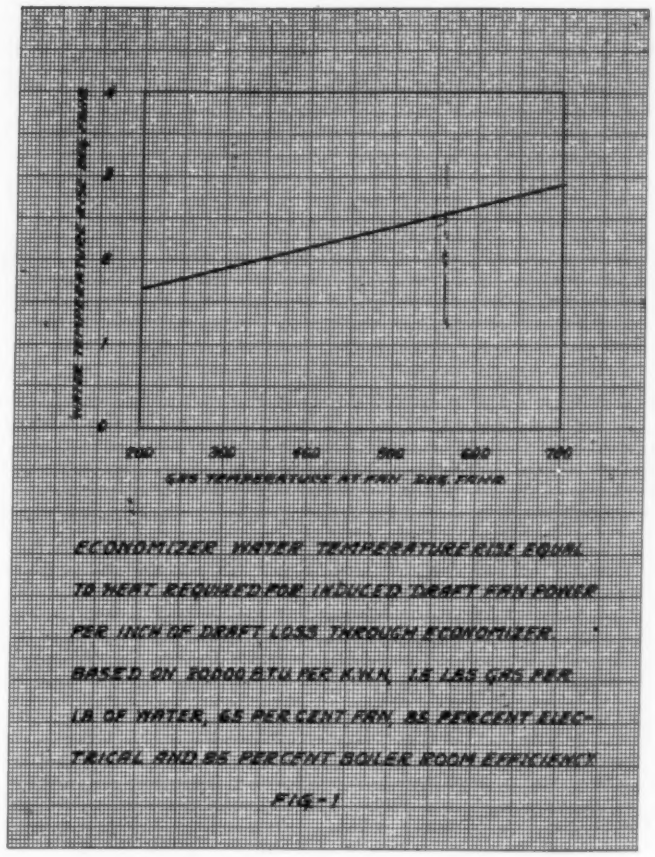

GAS TEMPERATURE AT FAN INLET, DEG. FAHR.
ECONOMIZER WATER TEMPERATURE RISE EQUAL TO HEAT REQUIRED FOR INDUCED DRAFT FAN POWER PER INCH OF DRAFT LOSS THROUGH ECONOMIZER. BASED ON 10000 B.T.U. PER K.W.H. 15 LBS GAS PER LB. OF WATER, 65 PER CENT FAN, 85 PERCENT ELECTRICAL AND 85 PERCENT BOILER ROOM EFFICIENCY
FIG-1

This and additional investment costs for motors, if they are larger than would otherwise be necessary, are the only costs which should be charged against draft losses in economizers and almost invariably these costs will be less than added investment costs of economizers for the same net performances but with lower dragt losses. In general it may be said that within reasonable limits the net annual return will be greater on high than or low draft loss economizer installations.

Water fed to steel tube economizers should be slightly alkaline and contain not over 0.3 cc oxygen per liter, preferably not over 0.2. These are conditions that can readily be maintained with only ordinary attention on the part of operators but in many plants adequately equipped for the maintenance of satisfactory conditions as to oxygen content of feed water, the making of oxygen determinations is not one of the routine duties assigned to operators with the result that an unsatisfactory and harmful amount of oxygen is present in the feed water. It is generally supposed that the making of oxygen determinations is a difficult and complicated procedure. This is not the case. Figure II is a photograph of oxygen determination apparatus installed in the boiler room of the Lakeside Plant of the Milwaukee Electric Railway & Light Company. Oxygen determinations are made at regular intervals by regular operating personnel and each determination represents about one minute of operator's time. Putting oxygen measurement into the hands of the operating personnel has the added advantage that through it the operators acquire first hand experience in the control of the conditions which determine the amount of oxygen in feed water. If the operating force are given apparatus of this type to measure oxygen and told to keep it down to a certain standard the desired results will be easily obtained.

The heat available for recovery in air heaters or economizers is proportional to the weight of gas per pound of fuel. With oil, coal or natural gas firing 1 per cent of the heat in fuel can be recovered for each 35 to 45 degrees that gas is cooled. With blast furnace gas firing 1 per cent can be recovered for each 25 to 30 degrees.

Heat recovery in economizers is applied directly to heating of feed water before it enters boiler. This increases efficiency by reducing amount of work that must be done in boiler per pound of steam generated. For the same amount of fuel burned capacity is increased in the ratio that the heat added in boiler, superheater and economizer is to the heat added in boiler and superheater only.

Heat recovered in air heaters is not applied directly to the heating of water but is used to preheat, outside of the furnace, air that would otherwise have to be heated in the furnace. This increases efficiency by reducing the amount of fuel that must be burned per pound of steam generated. The work to be done in boiler, superheater and water walls per pound of steam generated is the same as without air heaters. For the same amount of fuel burned air heaters increase capacity by increasing furnace temperature thereby increasing the work done in boiler, superheater and water walls. Under such conditions the increase in capacity obtained would be accompanied by a small increase in boiler exit gas temperatures and a corresponding slight reduction in boiler efficiencies.

It is some times claimed that heat available for recovery is greater in air heaters than in economizers in the same proportion that temperature difference between inlet gas and air is greater than tempera-

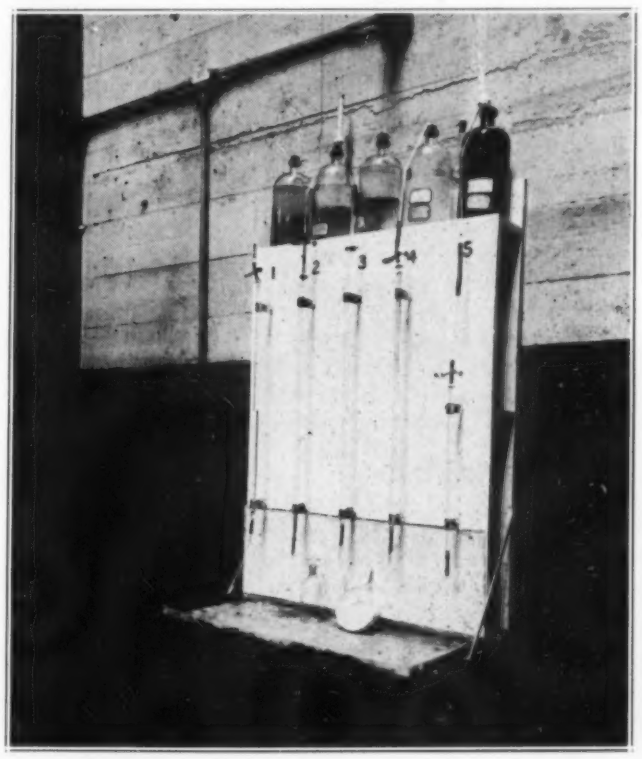


FIG. 2.

ture difference between inlet gas and water. This would be true if in each case the rates of gas temperature drop and corresponding air or water temperature rise were the same but this is not the fact. Under typical conditions the amount of heat available for absorption in an economizer is proportional to 100 per cent of the temperature difference between inlet gas and water, while in an air heater the amount of heat available for recovery is proportional to only about 75 per cent of the difference between inlet gas and inlet air.

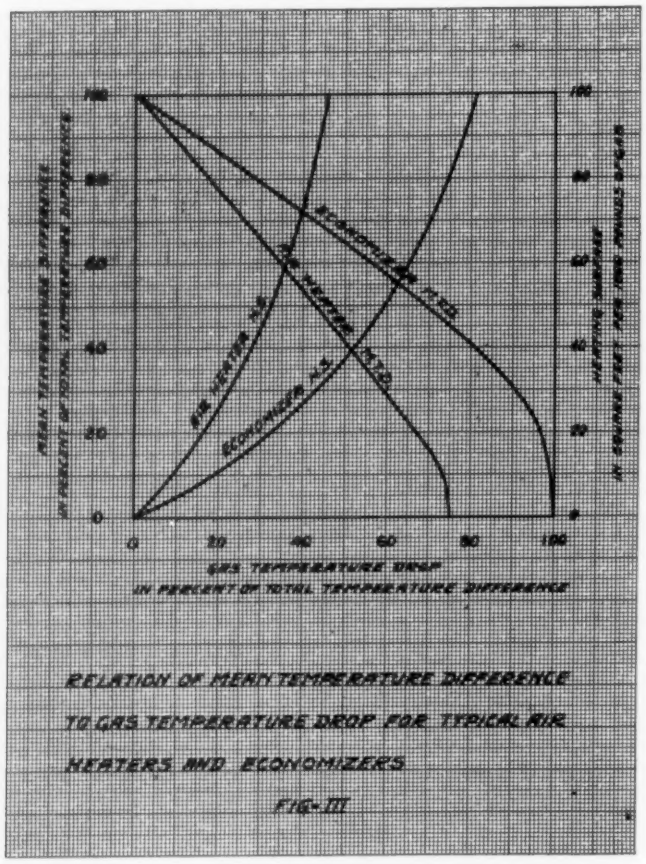

GAS TEMPERATURE DROP
IN PERCENT OF TOTAL TEMPERATURE DIFFERENCE
RELATION OF MEAN TEMPERATURE DIFFERENCE
TO GAS TEMPERATURE DROP FOR TYPICAL AIR
HEATERS AND ECONOMIZERS
FIG-III

Figure III shows for typical conditions in air heaters and economizers the relation of mean temperature difference and of surface required to amount of work done expressed as a percentage of the temperature difference between inlet gas and inlet air or water. These curves can be used for approximating economizer and air heater performances and surface requirements. In each case the amount of surface required is a function of the amount of work done expressed as a percentage of the total temperature difference between inlet gas and inlet air or water regardless of the amount of that temperature difference. For instance, other conditions being equal, exactly the same amount of heating surface would be required to cool gases through a range of 200 degrees with a total temperature difference of 400 degrees as would be required to cool them through a range of 400 degrees with a total temperature difference of 800 degrees.

In Figure III it will be observed that mean temperature difference in air heaters becomes zero when the gas has been cooled through a range equal to 75 per cent of the total temperature difference. At that point the air would be heated to the temperature of the incoming gas because the weight of air passing through air heater is only about 75 per cent of the weight of gas. The explanation of this is that only about 80 per cent of air supplied for combustion is put through air heater, the balance being admitted to furnace by infiltration through doors or other openings. The weight of all air for combustion admitted to furnace is about 92 per cent of the weight of products of combustion so that the weight of air through air heater, as stated above, is only 75 per cent of the weight of gas, the result being that air temperature increases at a greater rate than gas temperature decreases with the above mentioned result. In economizers the weight of gas is ordinarily about 50 per cent greater than weight of water and the rate at which water is heated is less than the rate at which gas is cooled and, therefore, the heat available for recovery is directly proportional to the total temperature difference.

Referring again to Figure III. As in all heat exchange apparatus the rate of work done per square foot of heating surface is proportional to mean temperature difference and decreases rapidly as the amount of work done is increased. This is indicated by steep slope of both curves, the mean temperature difference falling off at a greater rate in air heaters than in economizers.

Heating surface required in air heaters or economizers is equal to the gas temperature difference times the specific heat of gas divided by the mean temperature difference times the rate of heat transfer. The curves for surface shown on Figure III are based on the assumption that the average rate of transfer in economizers is 5.0 and in air heaters 2.5. The cost per square foot of economizer surface is about double the cost per square foot of air heater surface. Therefore in each case the return on investment per square foot of surface installed is approximately proportional to the mean temperature difference. Assume that for an economizer installation the incoming gas temperature is 600 and incoming water temperature 200. The total temperature difference will be 400. Assume further that in order to show satisfactory return on investment it is necessary to recover 1200 Btu. per sq. ft. of surface installed. This would require a mean temperature difference of 240 or 60 per cent of total temperature difference. The corresponding amount of work done would be 56 per cent of total temperature difference or 224 degrees of gas cooling. The surface required would be 44 sq. ft. per 1000 lbs. of gas. Compare this with an air heater installation with 600 degrees inlet gas temperature and 80 degrees inlet air temperature. The total temperature difference would be 520 degrees. The mean temperature difference should be 240 degrees the same as in an economizer to show the same return on investment and this would be 46 per cent of the total temperature difference. The corresponding amount of work done would be 46 per cent of 520 degrees or 240 degrees of gas cooling. The air heater surface required would be 100 sq. ft. per 1000 lbs. of gas. The cost of such surface would be about equal to the cost of 50 sq. ft. of economizer surface so that the cost of air heater would be 14 per cent greater than the cost of economizer and the work done 7 per cent greater.

Assume another case with temperature for inlet

gas 750, inlet water 250, inlet air 80. For an air heater installation total temperature difference would be (750-80) 670. Install 100 sq. ft. of surface per 1000 lbs. of gas. Gas temperature difference would be (.46x670) 308 and final gas temperature (750-308) 442. As an alternate consider the installation at the same total cost of 25 sq. ft. of economizer and 50 sq. ft. of air heater surface per 1000 lbs. of gas. Economizer total temperature difference would be (750-250) 500, gas temperature drop (.38x500) 190. Gas temperature leaving economizer (750-190) 560. Air heater total temperature difference would be (560-80) 480. Gas temperature drop through air heater (.32x480) 154 and final gas temperature (560-154) 406. This is 36 degrees greater heat recovery with small economizer and small air heater combination than with large air heater only.

In like manner curves shown on Figure III can be used for checking and analysis of other similar air heater and economizer problems. On Figure IV are shown economizer design curves for gas weights ranging from 1.0 to 6.0 lbs. per lb. of water. For gas to water ratios above 4.17 water would be heated to temperature of incoming gas before gas is cooled to temperature of incoming water. Such ratios are encountered in waste heat work where gas temperatures entering boiler are so low that the weight of gas passing through boiler and economizer per pound of steam generated is very high.

With certain fuels air heating improves combustion results and is, therefore, entitled to credit for added efficiency in excess of that due to the actual amount of heat returned to furnace. In such cases air heaters only should be installed instead of economizers if conditions do not justify the use of both air heaters and economizers. On the other hand some engineers are disposed to credit to air heating improved combustion results which it seems more likely to believe are primarily due to improvement in designs of firing equipment and methods of operation. So far as I know few, if any, reliable data are available showing definitely that with coal firing air heating has produced a greater increase in boiler efficiency than that corresponding to the actual amount of heat returned to the furnace.

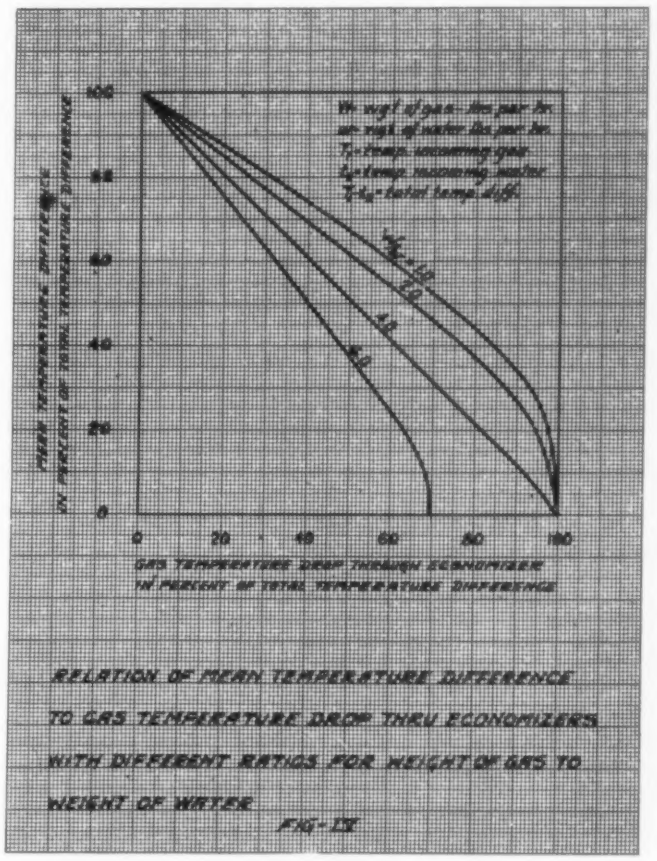
In conclusion the question of air heaters versus economizers may be summarized as follows:

1. Where load factor, cost of fuel and other conditions justify only moderate recovery of heat from boiler exit gases air heaters only should be used if it is known with certainty that preheated air is essential for good combustion results. Otherwise net returns on air heaters and economizers should be compared. On a close choice economizers are to be preferred because of greater compactness, elimination of hot air ducts and generally speaking a neater layout.

2. Small economizers and small air heaters in combination will usually show better returns on money invested than large air heaters or large economizers only. In the design of air heaters and economizers in combination it is often possible to figure advantageously on higher gas temperatures leaving boilers than would otherwise be practicable. This will reduce costs of complete steam generating units by reducing costs of boilers and—depending on design of boiler—may reduce cost of superheaters.

3. Large economizers only can some times be justified under conditions where the inlet water temperature is about 200 degrees and steam temperature is 400 degrees or higher so that there is liberal margin below steaming temperature for work to be done in economizers. There are also cases where steaming economizers can be justified. This applies particularly where exit gases from the boiler are unusually high.

4. In central stations with turbine stage bleeder feed water heating feed water temperatures are often so high that the advantageous application of economizers would seem to be impossible. In such plants, however, boilers as a rule are operated at very high ratings and, due to this and high steam pressures and correspondingly high saturated steam temperatures, boiler exit gas temperatures are so high that there is ample temperature difference between exit gases and incoming water for satisfactory economizer application. There is also so much heat in boiler exit gases to be recovered that it is hardly practicable to do it all in air heaters. In this type of plant, therefore, it is not unusual to install combination economizers and air heaters in spite of high feed water temperatures due to bleeder feed water heating.



RELATION OF MEAN TEMPERATURE DIFFERENCE TO GAS TEMPERATURE DROP THRU ECONOMIZERS WITH DIFFERENT RATIOS FOR WEIGHT OF GAS TO WEIGHT OF WATER.

FIG-IV

5. In many cases the choice between alternate propositions on performance considerations only is very close and selection of equipment should be based on layout advantages. In all cases layouts should be carefully analyzed before a choice is made. Inevitably better performances will be shown in plant that is well laid out than in one that is not.

6. An outstanding characteristic of all heat exchange apparatus that should always be borne in

mind in the consideration of economizers and air heaters is that beyond some critical size return on investment decreases rapidly as the amount of work done is increased. It is, therefore, usually advisable not to attempt the installation of the largest possible economizer or largest possible air heater and when conditions seem to justify the recovery of an amount of heat that is greater than can easily be done in an air heater or economizer in a single unit of moderate size it is usually better to install an economizer of moderate size in combination with a moderate size air heater.

The Use of Motion Pictures to Illustrate the Generation of Involute Gearing and the Use of Motion Pictures and Polarized Light as a Method of Studying Gear Stresses

By W. H. HIMES* and R. V. BAUD†

INTRODUCTION

Our reason for discussing gears and gearing in this popular way is that we assume that the Iron and Steel Electrical Engineer is too busy to go back to his old text books and renew his contact with gear theory, although he is confronted with gear problems with increasing frequency, now that electric power drives are becoming more numerous.

Therefore, this movie course in gearing is offered in the hope that it will be both timely and instructive. No radically new theory is offered in this paper nor any advanced data. Our best claim to consideration is that of the new aspect from which we have treated an old theme. We believe that the motion picture makes such a presentation to the eye that principles, only vaguely comprehended before, become clear and, what is more important, the mind retains the picture. As far as we know the motion picture camera has never been used to explain gear theory and performance. This vehicle has also enabled us to bring to you the revelations of polarized light, as well as though you were actually present in our Research Laboratory, where the studies in polarized light are being made.

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I. THE DEVELOPMENT OF THE INVOLUTE GEAR

Primarily two mating gears have the purpose of

transmitting uniform rotary motion from one shaft to another, at some predetermined velocity ratio. Among the very obvious devices for this purpose is the belt. Consider now Figure 1. Here we have

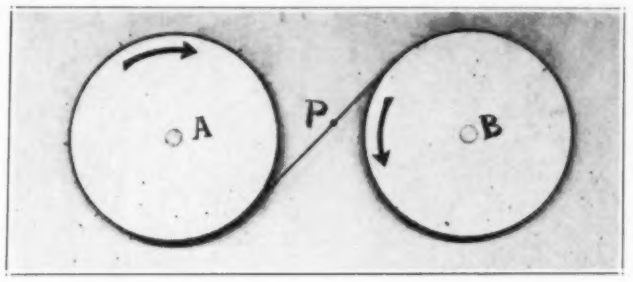

FIG. 1—Two pulleys with a crossed belt.

two pulleys connected by a crossed belt. Pulley *"A"* is exerting torque on pulley *"B"* through a belt assumed to be unstretchable. There can be no question that this device transmits uniform rotation. Equally obvious is the fact that any point on this belt, as at *"P"*, is moving in a straight line as soon as it leaves the surface of the driven pulley, and until it contacts with the driver. Now if we just consider the path of this point in space, or with reference to the field of the screen, there would be little more to say. If, however, we begin to pry into the path of this point with reference to the rotating pulley, the problem becomes more intricate. Let us see how this straight line path would look if observed from the rim of the pulley. Observe that we have backed up the pulley with a disc that rotates integrally with the pulley. We shall insert into the belt at the point *"P"*, a pencil, which will leave its trace on the disc as it passes over it. (At this point in the presentation, a motion picture will be introduced showing the generation of an involute curve). Several of the finished curves are shown in Figure 2.

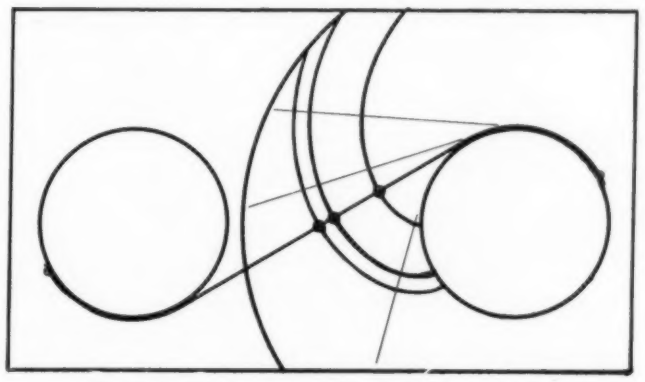

FIG. 2—The properties of the involute.

Now we see that while the point *"P"* draws a straight line in space, it traces a graceful curve with reference to the pulley. This you will probably all recognize as the involute, and the pulley rim is its base circle. It has properties different from any other curve. It is drawn from a constantly changing radius—which radius is always tangent to the base circle. We may then call it a tangent radius. Being a true radius, it always makes a right angle with the curve it generates, as is shown on Figure 2. Another important property which is obvious from these views is the fact that the perpendicular distance between any pair of involutes is always the same no matter how far we go from the base circle. There is no parallel to this condition with spirals as far as we know. It is necessarily so because each curve must always pass through its generating point on the belt or tangent. We have agreed that the belt is not elastic so the intersection points for any two curves must always remain the same distance apart.

It is these two properties of the involute which make it so useful in the generation of gear teeth. So let us emphasize these two points,—the curves are always at right angles to their tangent radii, and the perpendicular distances between any two involutes is the same at all points.

Next, in Figure 3—we have shown what happens when the generating point starts from the other disc. A new involute has been generated by the same

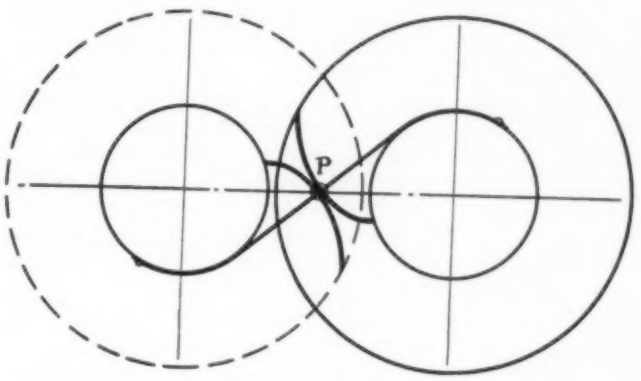

FIG. 3—Two involutes generated from a common generatrix.

point. Necessarily both curves pass through the same point so that they are tangent to each other as shown. We should expect then that, whichever direction our set runs, the two curves will remain tangent as they must always pass through their common generating point on the belt. (In the presentation a motion picture will be introduced to show the conjugate action of the two curves.) In this latter the two involutes are not in actual contact. The new one is painted on a disc of glass overlapping the original disc, so that both involutes can be seen at once. It is obvious, however, that if these were cams instead of curves, they might roll against each other and the belt could be dispensed with. We should still have uniform rotation. A series of such cams on the periphery of a wheel, so close together that one set is always in engagement, constitutes an involute gear.

Now, suppose we find that it is necessary to change the center distance on a set of existing gears. With the old cycloid or any other system, this will not do at all. They must run on their correct centers or else vibrate seriously. But let us consider Figure 3 again. What is to prevent our increasing the distance between these two discs a reasonable amount? Suppose that while one disc remains stationary, the other shaft is moved away the desired distance. As the belt being attached to the other disc cannot follow, the generating point also maintains its position. As the belt can neither move nor stretch, the disc and involute will rotate (unwind-

ing on the belt) as the shaft moves. But the two involutes must continue to pass through the generating point as long as the belt remains tight—we have just proved this. Therefore, even though the center of the disc moves away, the involute still passes through the generating point and, therefore, is still tangent to the other curve and the two gears will still roll with uniform rotation. (At this point in the presentation a motion picture will be introduced demonstrating the foregoing principle. In this film the left disc remained stationary, and the right disc rolled away from its mate on the belt like a coin rolling out of its wrapper. After a considerable separation, the two discs were rotated again showing perfect functioning, of the tangent curves, from the new position as before. This film makes it apparent that two involutes will perform as well at one center distance as at another, at least as far as geometry is concerned.)

The Involute Rack

Owing to the fact that these mating involute cams make their contact along the path traveled by the belt, the belt line is called the line of action. The point at which this line crosses the line of centers is called the pitch point. By similarity of triangles, it may be shown that if two tangent circles are drawn concentric with the base circles and passing through the pitch point, they will be exactly proportionate in size to the base circles. Consequently, they will roll on each other without slipping when the belt is in operation. These circles are more convenient for the draftsman to use than the base circles. They are just as effective in determining speed ratios as is the other set. Most gears are laid out without using the base cicles at all. We are illustrating here (Figure 4) a conventional pair of gears with these so-called pitch circles shown.

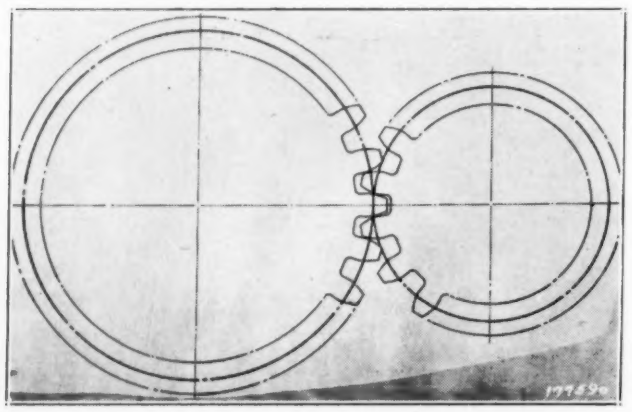

FIG. 4—Conventional gears with pitch circles.

It will be of interest next to consider the effect on the involute proportions when one of the gears is very large—so large that only a small portion of it may be shown on the screen. If one gear has a radius of a hundred feet and we showed a small portion of the rim, we should scarcely be able to detect any curvature at all. If the radius were considered infinite, we should, without hesitation, consider any finite part of the pitch circle as a straight line. Accordingly (Figure 5), we show here a gear of usual proportions with its pitch circle. Tangent to this pitch circle, is a straight line which may represent a part of the pitch circle of a gear of infinite radius. Such sections are useful in the arts and they are

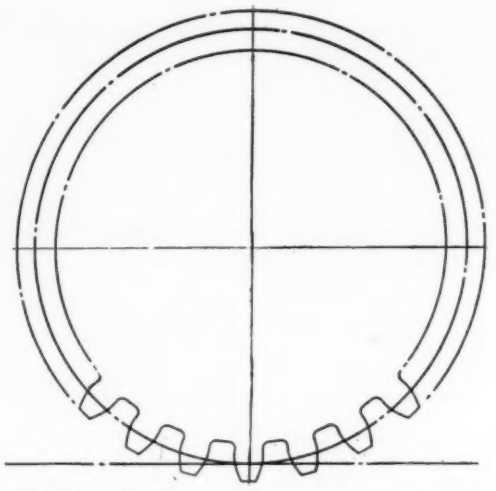

FIG. 5—The involute gear with section of rack pitch line.

called racks. If we desire to construct the teeth of this rack, we cannot proceed as before, because with an infinite radius we have also an infinite distance from the pitch circle to the base circle. It is, therefore, not practical to generate the involute curve for the rack. However, we have our pitch point and we know that the line of action passes through this point, and that it is tangent to both base circles, and one of them is finite, so we can locate the line of action (Figure 6) as shown here. Now we have seen that the involute is always at right angles to

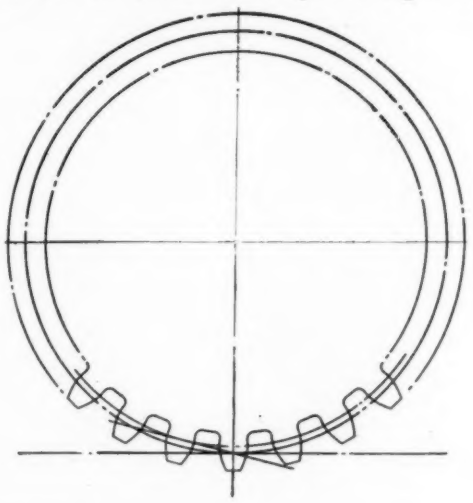

FIG. 6—The line of action for rack teeth.

the line of action, at least at the point of intersection. (Figure 7)—On this sketch we have drawn a line through the pitch point at right angles to the line of action. As this involute is an infinite one—the portion we are interested in will be a straight line. We, therefore, have our involute rack tooth determined. Most of you probably know from experience, at least, that the involute rack has a straight sided tooth. (Figure 8) Here we have finished our rack and are ready to test its action. The principles of the set-up are not quite the same as

previously because it is inconvenient to run our belt out to infinity to connect with the infinite base circle. But we have seen that the two pitch circles run on each other without slipping, so we shall attach our

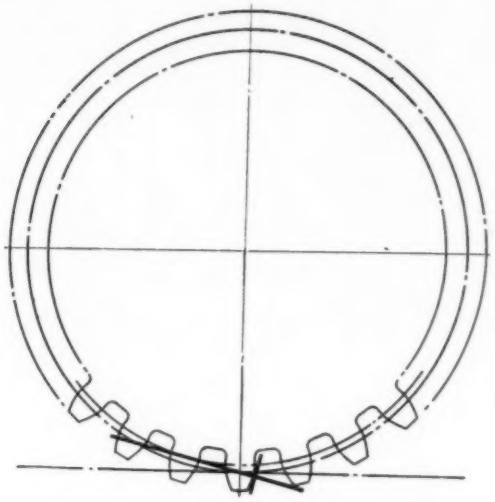

FIG. 7—The profile of the rack tooth.

belt to the rack at the pitch line and wrap it around the pitch circle of the gear. (The film which will be introduced at this point moves slowly enough to

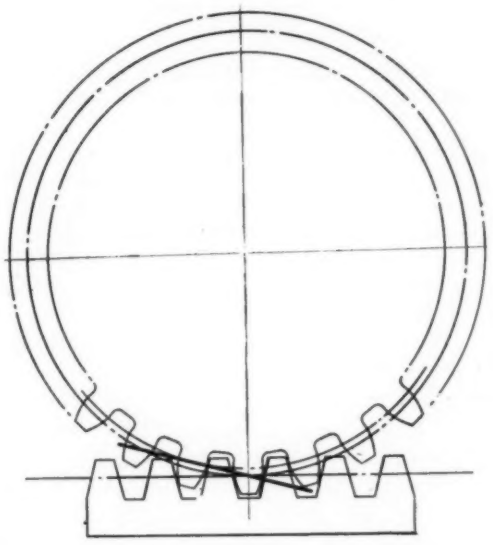

FIG. 8—The completed rack.

show that the straight sided or infinite involute tooth coasts perfectly with a regular involute gear. We know that we are getting uniform velocity transmission because the belt takes care of that, and if the mating curves were not correct for uniform motion, they would not remain exactly tangent to each other. We observe, however, that at least within limits, which the eye can detect, the action is perfect.)

The Rack as a Gear Tooth Generator

Thus the rack tooth is very simple to lay out—it is a straight line at right angles to the line of action. Machinery builders take advantage of this fact to construct involute gear cutters of straight sided blades, having the same angle as the rack. It is easier to construct a straight blade accurately than any form of curve. We shall now show how the straight blade can be made to generate the true in-

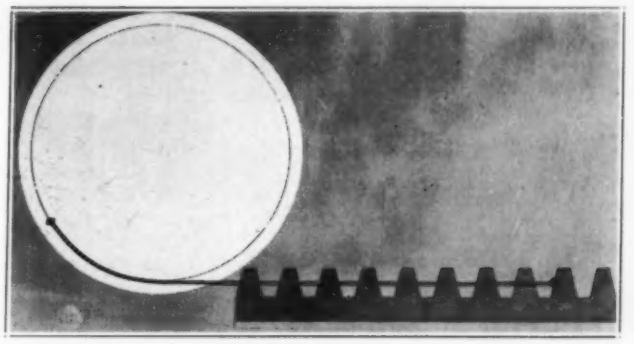

FIG. 9—The involute generating rack.

volute (Figure 9). Here we have a gear blank whose theoretical pitch circle is shown. It is located so as to be tangent to the pitch line of the generating rack, which is shown in black. This is supposed to have sharp edges so as to act as a cutter. In order to move the rack at the right speed, as the gear rotates, we can drag it by a cord wound around the pitch circle of the gear.* The cutting motion may be provided in various ways. This rack might reciprocate at right angles to the plane of the screen. The machine would then have to provide the rack with a motion conjugate to the rolling of the blank and simultaneously a reciprocating motion at right angles for the cutting. Another method of getting the same result will be suggested by the next film. This looks like another view of the gear and rack. Notice that the two ends of the lower member are concealed behind shields at the sides. Now we shall throw a little more light on this subject.† We find here a very simple means for securing both the cutting motion and the progressive motion needed for a gear cutter. In fact, if we cut teeth in the worm here shown, we have what is called a hob. To cut gear teeth with a hob, the gear must rotate at a pitch line speed equal to the apparent axial movement of the hob teeth and as the hob rotates, it is brought closer to the gear rim until the teeth are cut to the desired depth.

This concludes the study of gear generating and we shall now take up the subject of stresses in the gear teeth when under load.

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*This strip of film was taken in short sections—first the rack was pulled forward until it slightly overlapped the gear blank. The outline of the overlap was cut out of the blank and a short section of the film taken. The movement of gear blanks and rack carried forward a little farther and another slice was traced. This performance was repeated until several well-formed teeth were generated. As you see the successive steps forward of the rack, little imagination is needed to think of the paper blank as one of metal and the paper rack as a steel cutter whose successive steps are progressive cutting positions in a gear generating machine.

†At this point a motion picture is shown disclosing a gear rotating in mesh with what appears to be a rack. The rack emerges from behind a screen on one side, and disappears behind a screen on the other side of the view. When front illumination is thrown on the set, the rack is seen to be the top surface of a rotating worm, having no axial displacement whatever.

II. PHOTO-ELASTICITY

Introduction:

The problem with which the engineer is generally confronted, is to design a structure so that the two major factors, economy and safety, are well balanced. Sometimes specifications call for certain equipment so as to meet special conditions. It happens, for instance, that the space for engines and machinery is limited and in all such cases it is of importance to know as exactly as possible the load limit to which a machine element of given dimensions can safely be subjected.

Unfortunately, the nature of the problems quite often is such that even the closest analytical computation results in a rough approximation only. In a large number of cases conditions are further complicated due to the fact that the machine element is in movement as, for instance, in gears. The design of gear teeth for strength has, for many years, been based on certain assumptions as to the instant of maximum stress. It is obvious that a check of such assumptions should be carried out whenever possible and moving pictures and polarized light offer an extremely valuable means in this respect.

The Principles Involved in the Photo-Elastic Method:

The photo-elastic method involves the use of transparent models of such materials as, for instance, celluloid or bakelite. These materials are commercially available in flat sheets of suitable thickness, about ¼". When they are unstressed they transmit light with equal velocity in all directions. Such materials are called isotropic. When a substance transmits light at greater velocity in one direction than in another, it is referred to as aeolotropic.

The fundamental principle of the photo-elastic method is the fact that transparent isotropic materials become aeolotropic and double-refractive when subjected to stresses.

It is in order to refer at this time to the nature of light. Light, according to modern physics, is an electro-magnetic disturbance. However, in order to explain the further phenomena in a simple manner, let us assume that there is one vibration only. This vibration is transverse to the direction of light propagation. If this vibration is oriented at random, then we have ordinary light, i.e., light which has not been tampered with; the vibrations of such light are conceived of as not confined to any special plane, but they are as impartial as to their plane of vibration as the spokes of a wheel. On the other hand, if the vibrations are confined to one plane, that is, to two spokes of a wheel, placed oppositely, we call it plane polarized light. This is the type of light used in photo-elastic tests.

It was mentioned that transparent aeolotropic materials are double-refractive and, therefore, a ray of plane polarized light is split into two such rays. In Figure 10 let the point O represent the point at which a plane polarized light ray passes through a plate, and let OA represent the light vector of this incident plane polarized ray, i.e., the vector representing the plane of polarization and the amplitude of the light vibration. If the plate is unstressed, the light will pass through it without being substantially affected. If, however, the plate is stressed, the light-vector OA is resolved into two component light vectors OB and OC at right angle to each other. Since the material in loaded condition is aeolotropic, that

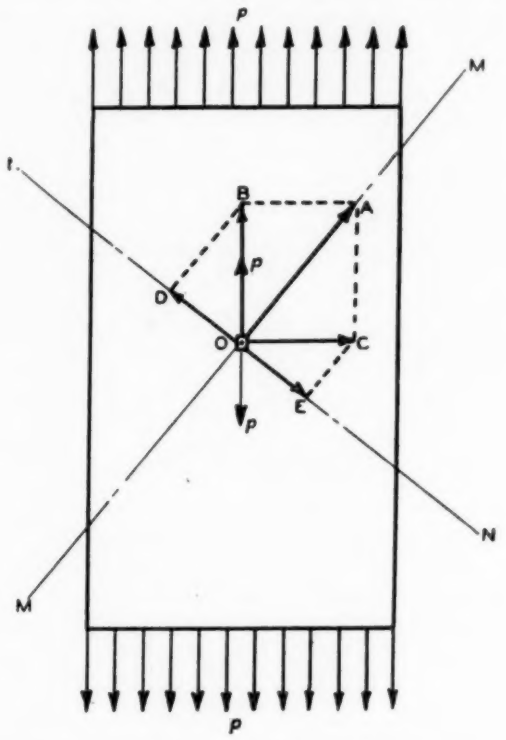

FIG. 10—Diagram of light vectors in a flat transparent plate axially loaded in tension.

is, it has different properties in different directions, the velocities of the two component light vibrations become different, so that finally, when leaving the plate, the two component vibrations will have a difference in time phase. This difference in time phase is denoted further on by R_m and its magnitude is given by the equation $R_m = c\ p\ t$
where c is an optical constant, t the thickness of the plate and p the stress.

In order to have the two vibrations reunited in the same plane, an analyzer (1) is inserted after the model, so oriented that only component vibrations in the plane NN perpendicular to MM are allowed to pass—see vectors OD and OE in Fig. 10. Since the light vibrations represented by vector OD and OE have their origin in the same light source, the phenomenon of light interference takes place, which phenomenon in the case of white light finally results in a colored spot on the screen. Since the color depends upon R_m and R_m depends upon the stress p, *the color is a measure of the magnitude of the stress* p.

It is obvious that if we have an additional stress q acting in a direction perpendicular to the direction of the stress p, Fig. 11, the difference in velocities of the two component vibrations discussed above will depend upon the difference between the stresses p and q and the difference in time phase becomes $R_m = c\ (p - q)t$, so that finally the color on the screen will depend upon the magnitude of $(p - q)$, i. e. upon the magnitude of the maximum shearing stress s_{max} since $s_{max} = \frac{p - q}{2}$

The phenomena will be the same whether we have

the whole plate uniformly stressed, Fig. 11, or only a small element of the plate. It is evident that in the general case a plate is not uniformly stressed, but the stress p and q vary from element to element, Fig. 12. The color, therefore, also varies and thus the color picture of the model projected on the screen gives us

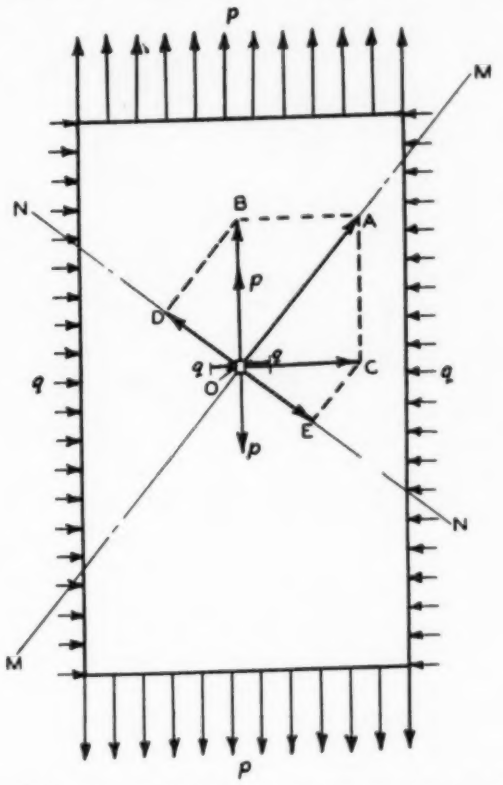

FIG. 11—Diagram of light vectors in a flat transparent plate axially in tension and laterally loaded in compression.

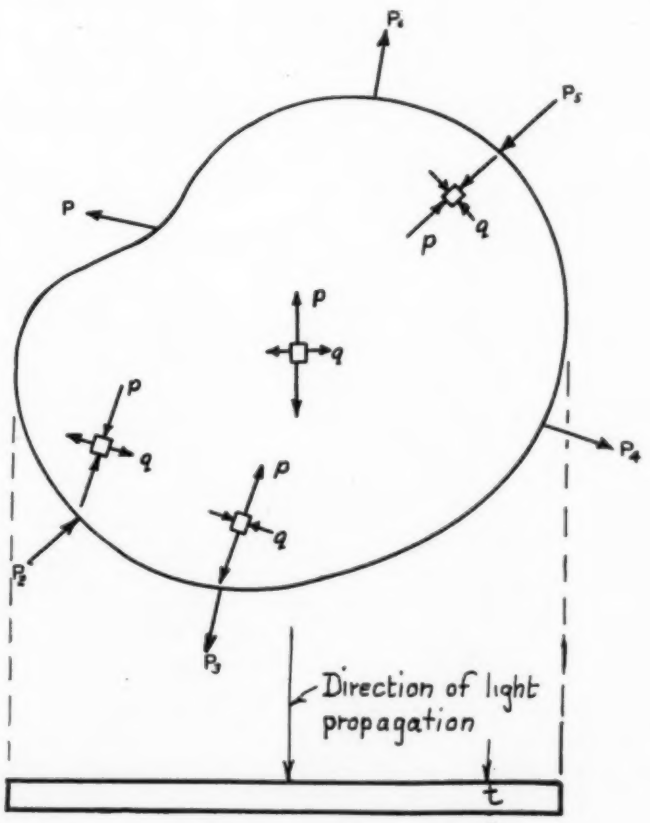

FIG. 12—Diagram of stressed plate indicating the varying values of stresses p and q.

FIG. 13—Photograph of cantilever test piece (Fig. 15) with large fillet radius showing bands of (p — q) constants.

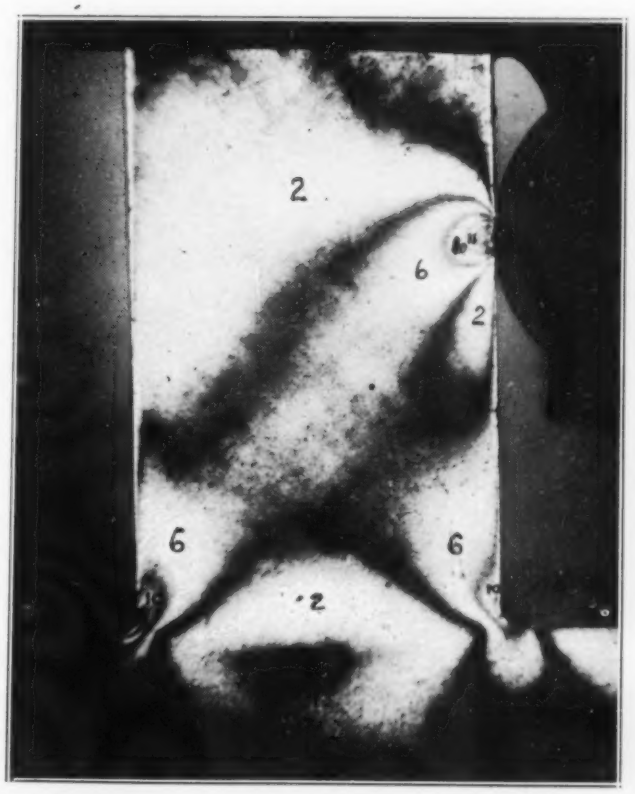

FIG. 14—Photograph of cantilever test piece (Fig. 15) with small fillet radius showing bands of (p — q) constants.

the complete information about the distribution of maximum shear stresses in the model.

In order to obtain a permanent record of the stress distribution, color photographs can be made. However, such photographs are not so convenient for reproduction as ordinary black and white photographs. Examples of such pictures are given in Figures 13 and 14. They show the stress distribution in models subjected to bending for the bending arm *l*, as being equal to one inch. Other dimensions of the models are given in Fig. 15. These models were used also for tests to destruction. These tests are described later on in the paper. We find in these stress distribution pictures bands of uniform darkness and brightness. For each of these bands a number is given in Figs. 13 and 14. In order to get an approximate picture of the magnitude of the stresses, the table following may be consulted:

TABLE I—COLOR SCALE

Order	Color	Black and white shades as photographed by ordinary process	Band Number see figures and	Stress p or stress difference $p-q$ in lbs. per sq. inch
	Black	Black	0	0
	Gray	Gray	1	0- 620
	Yellow-Orange	White	2	620- 920
I	Red-Brown	Gray	3	920-1200
	Blue-Green	Black	4	1200-1550
	Light-Green	Gray	5	1500-1650
	Yellow-Orange	White	6	1650-1920
II	Red-Brown	Gray	7	1920-2170
	Blue-Green	Black	8	2170-2400
	Light-Green	Gray	9	2400-2540
	Yellow-Orange	White	10	2540-2800
III	Red-Brown	Gray	11	2800-3060
	Green	Black	12	3060-3590
	Yellow-Orange	White	13	3590-3820
IV	Red-Brown	Gray	14	3820-3960
	Green	Black	15	3960-4560

Maximum darkness is produced at the boundary line between dark brown and blue or dark brown and green. Maximum brightness is produced by clear yellow.

The method of obtaining lines of equal color or lines of equal black and white shades, i. e. lines of equal shear stress, is only approximate when materials of a low index of forced double refraction are used. It can be improved considerably by using material of a high index of forced double refraction and by using as a comparator a strip of the same material, in bending instead of tension. (2) In order to obtain very accurate measurements a compensator is used instead of a comparator.

Application of the Photo-Elastic Method to Design Problems in General

Now that we have seen how the stress distribution in transparent materials is obtained, it is natural, and to be expected, that the question arises—what benefit can the designer derive from such tests for the materials he generally has to deal with; i. e. *iron and steel?* This problem, of course, has been studied carefully and it is established that, within the elastic stage, *the stress distribution does not depend upon the material, as a rule.*

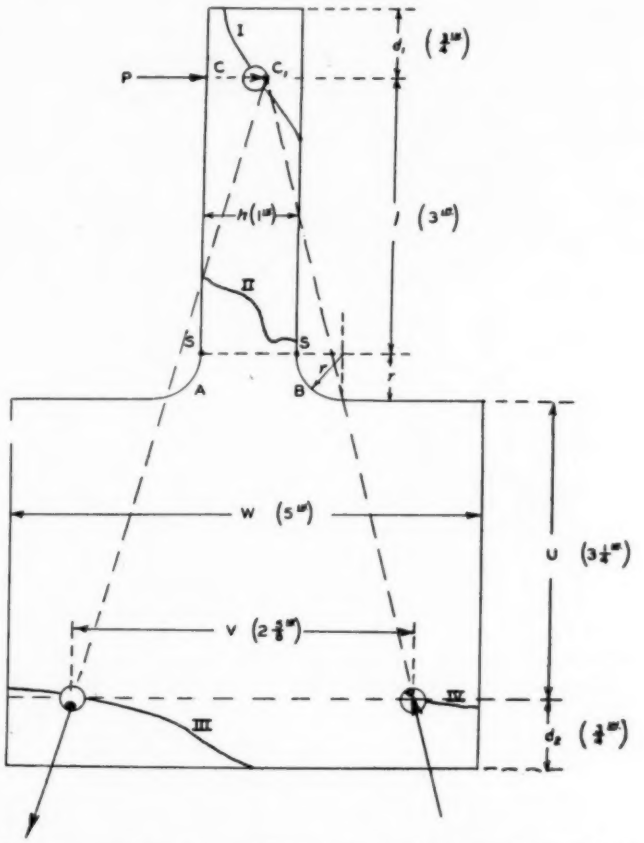

FIG. 15—Sketch of cantilever test piece used to obtain Figures 13 and 14 and to obtain data on failure.

To illustrate this statement, we shall discuss the well-known beam or flexure formula:

$$p = \frac{M}{S} \qquad (1)$$

in which for the case shown in Fig. 15

p = *Stress*

$M = Pl$ = *Bending moment*

$S = \frac{th^2}{6}$ = *Section modulus.*

See Fig. 15 for notations.

It is noted that the equation (1) *does not contain a material constant* and, consequently, holds for a beam of whatever material it is made, the only restriction being that the stress p shall not exceed the proportional limit (PL). The limiting bending moment is given, therefore, by the equation

$$M = S\ (PL) \qquad (1\,a)$$

The proportional limit is much higher for steel than it is for celluloid (say 100 times) and therefore, the load applied in the experiment will be, as a rule, much smaller than the one in actual service. But, evidently, if the stress p_1 for a certain element is known for a moment $M_1 = P_1 l$ applied to the celluloid model of the thickness t_1, it is a simple matter to compute the cor-

responding stress p_2 for a load $M_2 = P_2 l$ and a thickness t_2 of the steel structure, since

$$p_2 = p_1 \frac{t_1}{t_2} \frac{P_2}{P_1} \qquad (2)$$

that is, the stresses are directly proportional to the loads and inversely proportional to the thickness. This also holds for points inside, where in more complicated cases we have a crosswise stress q:

$$(p - q)_2 = (p - q)_1 \frac{t_1}{t_2} \frac{P_2}{P_1} \qquad (2a)$$

There exist groups of problems where the stress distribution *does* depend upon the material, but the deviation may be either within the accuracy of the experimental work of this type or may be taken care of by a correction factor.

It has been mentioned that the models are machined of flat sheets and they can, therefore, represent with accuracy only the cases of two-dimensional problems of stress distribution. However, tests with such models, especially designed to take care of the three-dimensional nature of the problem allow in a great many cases that some valuable conclusions sufficiently accurate for practical purposes be drawn also on more complicated three-dimensional problems.

Fillet Problem

A notable example, where the optical method has been applied very successfully, is the fillet problem, Fig. 13 to 15. ([3]) Factors of stress-concentration, K, have been established for various ratio of W/h and r/h, (see Fig. 15 for notations). Such factors must be included in the flexure formula in order to obtain the correct maximum fillet stress.

Equation (*1a*), therefore, reads as follows for the fillets:

$$M = Pl = \frac{S\ (PL)}{K} \qquad (1b)$$

where the expression (PL) represents the proportional limit, as has been mentioned, or

$$P = \frac{S\ (PL)}{l\ \ K} \qquad (1c)$$

In order to illustrate the importance of including stress concentration factors in the flexure formula, two models, as shown in Fig. 15, were made of transparent bakelite. Bakelite is brittle, i. e., its stress-strain line is practically straight up to fracture; the fracture stress being denoted further on by the abbreviation *Ult.*

The two models differed from each other only in that the fillet radii r were different; namely, ½" in the testpiece #1, and 1/16" in the testpiece #2.

For brittle materials equation (*1c*) may be written as follows:

$$P_1 = \frac{S\ (Ult)}{l\ \ K_1} \qquad (1d)$$

$$P_2 = \frac{S\ (Ult)}{l\ \ K_2} \qquad (1e)$$

Since the models were made of the same material and had the same proportions with the exception of the fillets, the following relation is obtained from equations (*1d*) and (*1c*):

$$\frac{P_1}{P_2} = \frac{K_2}{K_1}$$

i e., the loads are inversely proportional to the stress concentration factors.

In our case these factors were $K_1 = 1.8$ (*Ref. 3*)
$K_2 = 3.1$

and, therefore, $\frac{K_2}{K_1} = 1.71$

The models were subjected to an increasing load until finally fracture occurred. The testpiece #1 ($r = 1/2''$) fractured at $P_2 = 96$ pounds through the hole in the end, see fracture line I in Fig. 15. The load was then applied at point *C*. After it was increased to $P = 161$ pounds, three failures were obtained; see lines II, III and IV, apparently simultaneously. It may be, however, that the failure III occurred first and failure II afterwards, due to impact.

Testpiece #2 was loaded at point C_1 and failed through the tension fillet at a load $P_2 = 106$ pounds.

From this experiment it is seen, that the model I with the larger fillet withstood 52% more than the one with the small fillet. If the material has no ductility, whatsoever, and is completely uniform throughout, it is expected that the piece with the larger fillet will withstand 71% more than the one with the sharp fillet.

The tests were then repeated with models made of camphor celluloid, which is a ductile material. The breaking loads were:

$P_1 = 191$ *lbs.*
$P_2 = 176$ *lbs.*

$$\therefore \frac{P_1}{P_2} = 1.07$$

From this is seen, that for *ductile material* and *static* load, stress concentration in the fillet is not so dangerous. Since the ductility of the engineering materials most commonly used may be somewhere between the ductility of celluloid and that of bakelite, the reduction of the safe load by dividing by the quantity K could not be justified. A smaller reduction, say α/K times, is sufficient, where α takes into consideration the ductility of the material.

Application of the Photo-Elastic Method to the Gear Problem

If a cantilever model is loaded, as shown in Fig. *15*, and put in the field of polarized light for examination, two outstanding observations are made; see Fig. *13* and *14;* namely, (1) that very high shearing stresses are produced in the point of load application and its neighborhood, and (2) that the bending stresses are extremely high in the two fillets.

It will be noted that, after all, a gear tooth is nothing else than a more complicated form of the cantilever model, Figure *15*. Therefore, equation (*1*) can be used to compute roughly the safe load of a gear tooth. About thirty years ago Lewis had refined the flexure formula so as to conform more truly to the particular shape of the tooth.

The presence of concentration in the fillet has since been realized, and its magnitude has been measured photo-elastically for slender teeth. ([4]) Later on, it was observed that, in the case of stub teeth, the stresses at the compression fillet, are higher than those in the tension fillet. ([5]) This can be explained, however, by taking into consideration that the applied load produces compression stresses which for stub teeth penetrate

down to the root of the tooth, since the length *l* in Fig. *13* and *14* is very little in this case. A further discussion of this interesting fact is beyond the scope of this paper, but it will be realized how helpful the optical method is in the solution of the gear problem.

Motion Pictures of Rotating Celluloid Gears:

Various motion pictures, 35mm. film, of rotating celluloid gears have been made by us in order to determine the instant of maximum stresses in various points, to establish the increase in stress due to gear errors, and to study the effect of having different numbers of pairs of gear teeth in contact at the same time. Such pictures are valuable for two reasons: First, they represent a permanent record, which may be consulted at any time and, second, they allow the demonstration of gear phenomena to a large audience.

In making these ordinary black and white motion pictures, the peripheral speed of rotation was very slow; namely, 8″ per minute. It is contemplated, however, to repeat the experiments approaching normal speeds in order to study impact effects. The interpretation and application of the results of dynamic tests, of course, becomes more complicated than for static conditions, since tooth errors and the moment of inertia of the rotating masses, as well as the amount of tooth deflection, enter into the problem. The latter complication is present even in the static test when more than one pair of teeth is in contact.

Interesting results have been revealed by the moving pictures so far made; it was established, for instance, that for all commercial gears, which as a rule have a contact ratio less than 2, the instant of maximum bending stress is with the contact in, or near, the pitch point, because for this position of the gears one pair alone transmits the full load. Accordingly, in the motion pictures, a short flash of black and white shades is observed, which indicates a rapid increase of the stresses throughout the gear tooth at this point.

III Acknowledgment

The writers wish to acknowledge the assistance of Messrs. F. Paulson and E. V. Kaplan in carrying this work to conculsion.

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[1]) R. V. Baud—Description of a Polarized Light Apparatus for Photo-Elastic Work, Instruments, Vol. 1, No. 9, Sept., 1928, p. 393.

[2]) R. V. Baud—Further Development in Photo-Elasticity—Journal of Optical Society, Vol. 18, No. 5, May, 1929, p. 422.

[3]) S. Timoshenko and W. Dietz—Stress Concentration Produced by Holes and Fillets. Trans. A. S. M. E., Vol. 47, 1926.

[4]) S. Timoshenko and R. V. Baud—The Strength of Gear Teeth—Mechanical Engineering, Vol. 48, No. 11, November, 1926.

[5]) R. V. Baud—Study of Stresses by Means of Polarized Light and Transparencies—Proceedings Engineers' Society of Western Pennsylvania, Vol. 44, No. 6, July, 1928, p. 215.

Some Results of Boiler Water Conditioning

By R. E. HALL*

FOREWORD

Five years ago, we had the privilege of presenting some new theories on the mechanism and prevention of scale formation in boilers, in a paper entitled "The Prevention of Scale Formation by Boiler Water Conditioning." (1) The editor of the Iron and Steel Engineer was kind enough to pass favorably on and publish this paper(2), and hence this Association became first sponsor for the systematic boiler water conditioning therein proposed. During the intervening years the correctness of theories advanced in the paper has been fully demonstrated under the severest operating conditions, and the necessary procedure in their application reduced to simple routine. The process of so conditioning boiler waters has been designated "Hall System of Boiler Water Conditioning." Its fundamental departure from methods of water treatment hitherto practiced is evidenced by the basic patents granted to it.(3)

One prefers to talk or write about things he is actively engaged in doing, and so we believe we need make no apology for deciding to discuss Hall System in this paper. It is a pleasure, after a lapse of five years, to have opportunity to render an accounting thereof to this Association, and in so doing, to present the progress and some of the results attained in its application.

We wish to define what comprises Hall System, and shall do so by briefly describing some of the important steps in its development.

*Director, Hall Laboratories, Inc., Pittsburgh, Pa.

(1) At the April Meeting of the Combustion Engineering Division of the A. I. & S. E. E.

(2) "The Prevention of Scale Formation by Boiler Water Conditioning." R. E. Hall, Carl Fischer and G. W. Smith. Presented April, 1924, Pittsburgh, Pa.; published in Iron and Steel Engineer, Vol. 1, pp. 312-327, June, 1924.

(3) U. S. Patents 1,613,656 and 1,613,701, issued January 11, 1927, to R. E. Hall, and assigned to John M. Hopwood.

EARLY DEVELOPMENT: A GENERAL ANSWER TO THE QUESTION "HOW MUCH SODA ASH TO USE"

Origin of Investigation.

It was early in 1922 that Mr. J. M. Hopwood, President of the Hagan Corporation, came to Dr. A. C. Fieldner, then Superintendent of the Pittsburgh Station of the United States Bureau of Mines, with a proposal for a co-operative investigation on

the mechanism of scale formation in boilers. Dr. Fieldner, desirous of work along this line, but having no funds available therefor, welcomed the proposal, and an agreement was drawn to be effective for a few months or a year at most. The author was Physical Chemist for the Pittsburgh Station at that time, and to him was assigned direction of this problem as a minor part of his duties.

The general opinion prevailing at the time was that certain elimination of scale formation in boilers could be accomplished only by removal of scale-forming constituents in the entering feed water. Thereby, attention was focussed on low residual hardness in effluent water from the softener as the essential thing, to the exclusion of any careful consideration of the boiler water. True, much direct treatment of water by compounds of various kinds, or by soda ash, was employed; but there was no guiding principle by which certainty of results could be foretold, or by which varying conditions pertaining to different plants could be met save by arduous, cut-and-try methods.

There was another angle to the situation. Higher boiler pressures were becoming more common; the size of individual units was being increased; and water-cooled side-walls and screens to be feasible required complete freedom from scale. Such units might operate in condensing stations, although even there condenser leakage introduced uncertainty; but extension of their use to industrial stations with large make-up seemed of doubtful economic value. Outage of one or two of many small units could be tolerated; but continued possibility of outage of a large unit for tube replacements was out of the question. Thus, the developments in boilers created urge that uncertainties caused by water be eradicated.

For eighty years, methods of treating the feed water had received careful attention (4); meanwhile, exact consideration of boiler waters had been very limited since the investigations of F. Fischer, (5) in 1874-76, and weird ideas concerning them had lately been conceived by Paul (6) on the basis of totally fallacious reasoning.

Our point of attack fortunately was the boiler-water. Through shifting the focus of attention thereto, and by use of physico-chemical methods in analyzing conditions at the evaporating surfaces, an entirely new field was opened for development by the exact methods available in modern investigation. It is not surprising therefore that the investigation inaugurated as a minor problem at the Bureau of Mines for the period of a few months, was not terminated until more than four years later, when Hall Laboratories, Inc. was established as an agency whereby fundamental discoveries of the investigation might be converted into processes applicable under operating conditions. For a further period of two years, investigation was carried on by the Laboratories. When finally conditions pertaining to the boiler-water had been analyzed, it was clear that to obtain the exactitude essential for modern high-pressure, high-rating boilers, boiler-water conditioning must be the final step in water-processing, whether the preliminary steps be by softeners, evaporators or condensers.

(4) The original patent on use of lime is that of John Melville (Brit. Pat. 7652, 1838). The patent of Thomas Clark (Brit. Pat. 8875, March 8, 1841) is usually considered as the beginning of the water-softening processes. A history of development and bibliography are given in Bull. 24, Carnegie Inst. of Technology, (1927) pp. 10-15 and 39-45 (Hall and Associates.)

(5) F. Fischer, Ding. Polyt. J. **212,** 208-220; **212,** 296-308 (1874); **220,** 172-181, 261-268, 367-378 (1876); **222,** 166-174, 237-249 (1876).

(6) J. H. Paul. Boiler Chemistry and Feed-Water Supplies. Longman, Green & Co. (1919).

Deposition of Scale, in Situ.

Our early experimental work under operating conditions was conducted at the plant of the Mesta Machine Co., Homestead, Pa., in collaberation with Mr. Carl Fischer (7), Superintendent of Power. Working with untreated but filtered feed (city) water, we noted that the boiler-water was clear enough for drinking purposes, yet was responsible for deposition of 30-60 lb. of calcium-sulphate scale per day in the 545 H.P. Heine Boiler under observation. Hence one definite fact was established; namely, that boiler scale was not formed from minute particles in suspension throughout the boiler-water (8) which by chance lodged on a tube and remained there as scale. On the contrary, the scale was formed by direct crystallization from the boiler-water on the surfaces and never existed in suspension in the boiler-water. This mechanism of scale formation was designated formation **in situ;** and its correctness has been completely confirmed by the recent comprehensive investigation of Partridge and White (9).

Following the tests on untreated boiler-water, treatment with silicate of soda was attempted, in the thought that the finely divided precipitate, with its excellent flocculating characteristics, might largely decrease the amount of calcium sulphate going into adherent scale, without use of a large amount of silicate. The results were decidedly negative.

How Much Soda Ash?

As a next measure, decision was made to use soda ash as treatment. The problem confronted us, as it has doubtless confronted thousands of others:

(7) This work was summarized in Bureau of Mines Report 435-F-10 ("A 42-Day Test on a permanently Hard Water in a 545 H.P. Boiler, and a 76-Day Test on a Temporary Hard Water in a 1000 H.P. Boiler," Hall, Smith, Coleman and Fitch, November 19, 1923, Unpublished) and conclusions therefrom have been published as follows: Reference 2; "Boiler-Water Treatment from the Standpoint of Chemical Equilibrium," Hall, Smith and Jackson, Serial Report of the Prime Movers Committee, Publication No. 24-69, pp. 5-14, 1924; "A System of Boiler-Water Treatment Based on Chemical Equilibrium," Hall, Ind. & Eng. Chem. Vol. 17, pp. 283-290, 1925; "The Solid Phases Developed in Boiler-Waters," Hall and Merwin, Trans. Am. Inst. of Chem. Engrs. Vol. 16, Part 2, pp. 91-117, 1924.

(8) This is the theory of scale formation rather widely held at the period in question, and was supported by French (D. K. French, "Internal Treatment of Boiler-Water—Proper and Improper," Ind. & Eng. Chem. Vol. 15, p. 1239, 1923) and Partridge (E. M. Partridge, "The Sphere of Boiler Compound—Colloid Chemistry and Scale Prevention," Power, Vol. 60, pp. 56-59, 1924) in their advocacy of the use of colloids to prevent scale formation on the boiler surfaces.

(9) "The Formation and Thermal Effects of Calcium Sulphate Boiler Scale," E. P. Partridge and A. H. White—Preprint, Trans. Am. Soc. Mech. Engrs. 1929.

How much soda ash shall be used per million pounds or per thousand gallons of feed water? We did the natural thing, which was to select a quantity by guess, watch its effectiveness on decreasing scale formation by periodically opening the boiler for observation, and change the dosage accordingly. With a feed water of relatively constant hardness, such for instance as that from one of the Great Lakes, one would obtain in time an effective dosage for the particular pressure and other conditions of the one plant in question, but would necessarily resort to similar experiment for any other pressure, or different set of conditions.

One might perhaps by persistent experiment, establish roughly the changes of dosage essential to seasonal variations in hardness characteristic of rivers, small lakes, and many wells; but in this manner to establish a schedule of dosage for aperiodic variations in hardness due to rainfall is an utter impossibility. In any case, this empirical procedure is fraught with danger, since as demonstrated later, use of excessive amounts of treating chemical causes fully as much trouble as use of too little.

Answer to the question, "How much soda ash?" to be of more than purely local value, must be general in its application to all operating conditions, pressures, different types of water with their seasonal and aperiodic variations, changes in percent of raw make-up water, condenser leakage, etc. It must also be simple to apply, so that the operator of the boiler house, by routine tests, can at all times maintain uniformity of boiler-water conditions, however variable his feed-water may be.

Classification of Scale-forming and Sludge-forming Substances.

As mentioned, the experimental work at Mesta established the fact of scale formation **in situ.** This was the first step in a general solution of the problem, "How much soda ash?" since it made possible restriction of attention to those substances whose separation from solution in the boiler water is favored by conditions at the evaporating surfaces, especially the higher temperature existent in the film of water in immediate proximity thereto.

The second step in the general solution came from the research laboratory. Use of very simple apparatus demonstrated as correct the general conclusion that those substances whose solubility decreases with temperature increase are actively scale-forming when their saturated solutions are in contact with heating surfaces. This conclusion, therefore, gave a general and at the same time strict classification of substances that would form scale because of higher temperature in the water in contact with the evaporating surfaces. Calcium sulphate and hydroxide must be classified as scale-forming substances; calcium carbonate as non-scale-forming.

The General Solution of "How Much Soda Ash?"

Establishment of these two generalizations laid the foundation for a general solution to the question of "How Much Soda Ash?" by reducing it to a problem of desirable and undesirable chemical equilibria at the evaporating surfaces. Thus, since calcium sulphate is scale-forming, and calcium carbonate forms as sludge, one must use enough soda ash to make any calcium getting into the boiler-water combine with the carbonate thereof to form suspended calcium carbonate. I need not annoy you with details of the methods by which a chemist solves these problems. The answer, however, is definite, and consists in the maintenance of necessary ratios of carbonate to sulphate in the boiler-water. Thus, at an operating pressure of 125 lbs. and with 1000 p.p.m. of sulphate (SO_4) in the boiler-water, enough soda ash must be used to maintain 65 p.p.m. of carbonate (CO_3) therein; with 2000 p.p.m. of sulphate, 135 p.p.m. of carbonate is required. If the operating pressure is 175 lbs., however, for 1000 and 2000 p.p.m. of sulphate in the boiler-water, it is necessary to maintain 115 and 230 p.p.m. of carbonate respectively. In general, for pressures of 100 lbs. or over, it is well that the carbonate concentration shall not fall below 80-100 p.p.m., in order that incidental variations in operation shall not permit the maintenance of carbonate to fall below the desired limit.

The answer to the question "How Much Soda Ash?" was definite and general. Whether make-up water be from lake or river, whether it be variable or constant, whether it be treated in a softener or not, the operator possessing a curve showing the essential relation of sulphate to carbonate for his boilers, so gauges the chemical he supplies thereto as to maintain these relations. Whenever he deems necessary, he runs the simple routine tests for sulphate and carbonate in his boiler-water, in this way catches any changes in character of make-up water, and accordingly avoids the ills attendant upon either over or under-treatment. Thus, necessary changes in quantity of treating chemical keep pace with the changes in the feed water that necessitate them, and the boiler operator is totally master of his own destiny, so far as cleanliness of boilers is concerned.

Curves epitomizing the general solution were given in the original paper (10). At Mesta, where the original work was done, from the beginning of their application until the present, maintenance of the ratios they prescribe has been a satisfactory answer to water conditioning. In the five years that have passed since publication of the curves, so far as the author knows, no criticisms directed against them have been published; and in their wide application by the author and his associates under most diversified conditions, no reason has been found to modify them.

SECOND STAGE OF DEVELOPMENT: PHOSPHATE FOR WATER CONDITIONING

Need for a Stable Conditioning Chemical.

With the curves before us defining soda ash requirements for all varying conditions, it became a certainty that the answer to continuous cleanliness of the evaporative surfaces of a boiler lay not in removal of the last trace of calcium from the feed-water at any cost, but in maintenance in the boiler-water of those conditions which at all times assured satisfactory disposal thereof if it entered. Only in this way could unavoidable variations in primary processing of the feed-water, whether by softeners, evaporators, or condensers, be prevented from cumu-

(10) See Reference 2.

lation in the boiler-water with consequent menace to cleanliness of surfaces. Thus, the primary processing equipment constitutes not at all the final line of defense in maintaining clean surfaces, but merely the most economical means of preparing water for its final conditioning in accordance with requirements demanded by conditions in the boiler-water, and the operating pressure of the boiler.

The reason for a condition, hitherto deemed anomalous, became apparent in view of the curves. Of two boilers using the same softened feed-water, but operating at different pressures, as for instance 150 and 300 lbs., the one of lower pressure might remain satisfactorily clean, and that of higher pressure become seriously covered with hard adherent scale. Interpreted by the curves, this merely meant that the carbonate maintained in the boiler-water at the lower pressure was sufficient to assure combination of calcium and carbonate, but was insufficient to thus force the issue at the higher pressure. The obvious answer would seem to be to maintain sufficient carbonate in the latter boiler-water by supplying it with the requisite quantity of soda ash.

Obvious, certainly, but wrong. For it is a fundamental characteristic of sodium carbonate that it decomposes rapidly into caustic soda in the boiler-waters of operating boilers. This fact was befogged at the time in part by the erroneous conclusions of Paul (11) and in part by the rather widely prevalent idea that this decomposition could be deterred by presence in the boiler water of organic substances such as tannates or sugar (12). That such deterrence to decomposition of soda ash does not occur, was definitely proved by the author (13).

Since, as operating pressure increases, the quantity of carbonate required in the boiler-water likewise increases, and since, also, the rate of decomposition of carbonate increases under these conditions, it is apparent that at sufficient operating pressure a situation eventually develops in which it becomes both uneconomical and unfeasible to maintain the essential carbonate in the boiler water. By two factors this situation is precipitated at rather lower pressure than we then believed might be necessary. (In our work we consider approximately 160 lbs. the upper limit of pressure for use of soda ash as final conditioning chemical.)

1. The high causticity developed by decomposition of sodium carbonate very markedly increases foaming tendencies (14) and is therefore undesirable.

2. The high causticity readily exceeds that permissible in the boiler water if the ratios of sulphate to alkalinity recommended by the Proposed Rules of the A.S.M.E. Code are to be adhered to. (15)

Choice of Stable Chemical.

We concluded that the answer to conditioning boiler-water at higher pressures lay in substituting for the unstable soda ash a stable chemical of suitable characteristics, whose maintenance in the boiler-water would thus avoid uncertainties inherent in decomposition. Of such chemicals available, we chose sodium phosphate as best suited, and immediately set to work to obtain the necessary data on the quantities that must be maintained in available form in the boiler-water at various operating pressures. (16) When these data were finally obtained, the question of conditioning the boiler-water for all possible pressures was solved, since phosphate is stable at the highest possible operating pressures involved, (the critical pressure and temperature of water are respectively, 3200 lb. absolute and 705°F.)

In the case of the two boilers at 150 lb. and 300 lb. pressure, using water from the same softener, the answer to cleanliness of surfaces in both becomes very simple. The softener may be run to maintain the essential carbonate concentrations in the boiler-water at 150 lb. pressure; into the feed water of the 300 lb. boiler at some convenient point following the softener, is introduced sufficient sodium phosphate to maintain the essential concentrations of phosphate radical in the boiler-water. Results are all that could be desired. (17)

Some Possibilities of Boiler-Water Conditioning.

In the pressure range up to 600-750 lbs., and with make-up of a few or 100 per cent, the maintenance of the essential phosphate in the boiler-water results in cleanliness of evaporative surfaces so that no turbining is required. With waters containing considerable hardness, preliminary processing is advisable, but some natural waters, notably many of those of New England, can be used directly without primary processing. In the higher pressure range (above 750 lbs.) it is well that dissolved solids (especially chlorides) be kept at low concentration, because of the augmented reactivity of boiler-water directly with boiler metal at the higher temperatures characterizing these pressures. Anderson has thoroughly analyzed conditions and results at 1200 lb. operating pressure. (18)

By the maintenance of definite concentration of conditioning chemical in the boiler-water, provision is automatically made for removal of calcium, entering through condenser leakage, or carry-over from evaporator. Unless so cared for, such calcium has an unobstructed path to deposition as adherent scale on the tube surfaces. The same provision obviously applies to make-up water of a few percent, and thus the engineer is at liberty to choose softener, evaporator, or direct conditioning with no primary processing, on the basis of which will most economically provide desirable conditions in the boiler-water, and with certainty of clean surfaces in any event.

The residual hardness of effluent water from the softener as a criterion dominating choice thereof

(11) See Reference 6.

(12) For instance, U. S. Patent 1,572,944, issued to M. F. Newman. Many statements of this kind were made to the author in the early days of the investigation, and one within the past few months.

(13) Statement in Prime Movers Committee Publication No. 256-71, (1925-26) p. 12.

(14) "Phosphate in Boiler-Water Conditioning," R. E. Hall and Associates, J. Am. Water Works Association, Vol. 21, pp. 79-100, (1929). Trans. Am. Soc. Mech. Engrs., Vol. 50, p. 65, (1928).

(15) Section VII, A.S.M.E. Boiler Construction Code (1927), Paragraph CA-5, pp. 80-81. Parr and Straub, Bull. 155 (1926) and 177 (1928) Eng. Expt. Sta., Urbana, Ill.

(16) A summary of our reasons for choosing phosphate and of the work done to obtain necessary data is given in Reference 14.

(17) Hall, Trans. Am. Soc. Mech. Engrs. **47**, p. 803, (1925).

(18) John Anderson, Engineering. Jan. 13, 1928, pp. 55-58.

gives way to that of most easily and economically obtaining essential conditions in the boiler-water.

From the standpoint both of boiling conditions and prevention of embrittlement, it is essential that the alkalinity in the boiler-water be under definite control at all times. With soda ash as conditioning chemical there is no independency in control of alkalinity, since its unavoidable decomposition results in the formation of caustic soda in the boiler-water. As pointed out by the author in 1925 (19), use of phosphate gives independency of control, and hence permits maintenance of the embrittlement ratios at higher pressures. Variation of basicity in the different forms of sodium phosphate (mono-, di-, and tri-sodium phosphate) aids in accomplishing this end.

These examples are perhaps sufficient to illustrate the advantages of exact water conditioning based on the maintenance of requisite concentration of conditioning chemical in the boiler-water.

THIRD STAGE OF DEVELOPMENT: BOILING CONDITIONS

Some Factors Affecting Boiling.

Following formation of the Laboratories in 1926, practically two years were devoted to a laboratory and plant study of boiling conditions. I wish to touch on this phase of work only briefly, by summarizing the conclusions.

Contrary to the then generally accepted opinion (20) which attributed foaming largely to the presence of suspended material, we found that concentration and type of dissolved material in the boiler-water were the primary cause of non-coalescence of bubbles of steam, and hence of foaming. Our point of view, first published in 1927 (21) supported except in minor details the results of Joseph and Hancock (22) who had performed their experiments on a locomotive in the French Sudan. The later work of Foulk (23) conforms to these views. Our conclusions may be summarized as follows:

1. Every effort should be made to exclude from the boiler-water all saponifiable materials, as grease, oil, sewage contamination, as these are most inimical to good boiling. The alkalinity of the boiler-water should be maintained as low as possible as it accelerates saponification, favors peptization of suspended material, and diminishes the limits of tolerance of the boiler-water for other dissolved substances as sodium sulphate. In a clean boiler-water, these limits of tolerance are little affected by the justifiable amounts of suspended matter that may be present, but are quite variable with type of boiler, rating, and character of load.

2. We believe that it is inadvisable to depend upon chemical means as a defense against foaming. A large enough shot of anti-foam may be capable of quieting boiling conditions temporarily, but like the drug habit, leaves the user in sad plight if successive shots are too infrequent or if continuous feed is insufficient or interrupted.

3. When conditions of careful control of alkalinity in the boiler-water, systematic blowdown, and cleanliness from all saponified and saponifiable materials have been realized, the next steps depend upon mechanical aids such as careful control of water levels, proper baffling of the steam drum, uniformity of feed-water distribution, purifiers or separators at or beyond the steam nozzle.

The importance of exact water conditioning to boiling conditions, as well as to cleanliness of surfaces, is readily apparent. We have heretofore emphasized the necessity of maintaining conditioning chemical in the boiler-water in amounts established by the operating pressure and conditions prevailing in the boiler-water. We now emphasize the necessity of limiting its concentration to the essential amount so established. Supplying the boiler-water with unrestrained excess of conditioning chemical is quite analogous to over-eating. Both produce discomfort; but the boiler, untrained in drawing-room manners, voids the excess by belching it forth through the steam nozzle.

For conservative operation there is, therefore, a narrow roadway to follow. On one side lies insufficiency of conditioning chemical, and hence, formation of scale; on the other lies excess that must be avoided partly from the standpoint of economy, but mainly to obviate the disastrous consequences of carry-over.

It has been the province of this investigation to clearly demarcate this roadway for all conditions; Hall System provides the necessary means so that any operator once instructed, can follow it independent of outside help.

HALL SYSTEM METHODS OF CONTROL

After all, once a safe road is established, the guide-posts that make for ease in travelling it, may be readily provided. In Figs. 1 and 2 we present

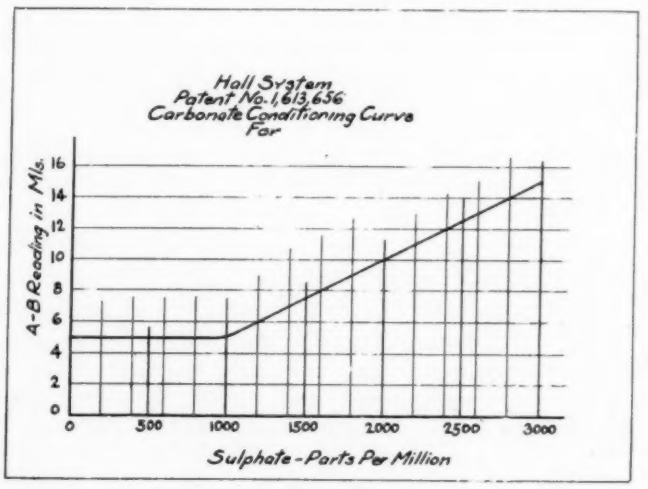

FIG. 1.

those guide-posts (each representative of a definite operative pressure) for carbonate and phosphate re-

(19) See Reference 13.

(20) Koyl, R. R. Gaz. **32,** p. 663 (1900); ibid. **34,** p. 423, (1902); Foulk, Ind. Eng. Chem. 16, p. 1121, (1924).

(21) Presented as discussion at the December, 1927, Meeting of the American Society of Mechanical Engineers, and included in the Transactions for that year. A summary of this work may be found as follows: Reference 14, Prime Movers Committee, Publication No. 278-81, pp. 46-49, (1928); J. Ind. Eng. Chem. Vol. 21 (1929), (not yet published).

(22) Joseph and Hancock, J. Soc. Chem. Ind., **46,** p. 315, T. (1927).

(23) Ind. Eng. Chem., 1929. (Not yet published).

spectively, that typify most characteristically Hall System, and that completely define for the operator in the plant, the middle of the road which he must follow.

Conditioning With Soda Ash.

The vertical axis in Fig. 1 which applies to use of soda ash as conditioning chemical represents the values obtained by titrating a sample of boiler-water with the test cabinet of Fig. 3; the horizontal axis represents the sulphate concentration, which is determined in the Sulphate Concentration Gauge (Fig. 4). The operator draws a sample of boiler-water from a point of the boiler which will give him a representative sample of the circulating water therein. He may take it from the blow-off cock of the gauge-column, after blowing it down well, or from other blow-down connection; in fact, from any point that will be representative of the bulk concentrations in the boiler-water. If, by his titration of this sample, he finds the concentration of his conditioning chemical to be in correct relationship to the sulphate concentration, he need make no change in the amount of soda ash that he is using. But if his concentration is too high, he diminishes the amount; if too low, he increases it. Thus, as a specific example, let us suppose that the sulphate concentration is found to be 1200 p.p.m., and that the titrations give an A-B Reading of 6mls. He knows at once that the amount of soda ash he is using is the right amount to protect him from scale formation and to interfere as little as possible with dryness of steam. Suppose, however, that the A-B Reading is 10 mls. he knows he is safe from scale formation, but is, to say the least, inviting trouble from wet steam by carrying higher concentration of conditioning chemical than necessary. He therefore immediately slows up the rate at which chemical is added, either by diluting the solution in his chemical tank or by retarding the rate of delivery from the tank. On the other hand, if the A-B Reading is 2 mls. he knows that he is not maintaining the necessary concentration of conditioning chemical to prevent scale formation, and hence increases the rate of addition.

Conditioning With Phosphate.

In Fig. 2, the horizontal axis represents sulphate in p.p.m., as in Fig. 1; but the vertical axis represents the concentration of phosphate in the boiler-water. Its concentration is determined in the gauge depicted in Fig. 5. It is designated as Yellow Reading because of the characteristic canary-yellow precipitate that collects in the capillary of the gauge, and which by its height therein, indicates the soluble phosphate in the boiler-water. Just as in the case of conditioning the boiler-water by the use of soda ash, the operator knows, immediately his tests are made, whether the amount of chemical he is using is too little, correct, or excessive, and at once takes appropriate action. His A and B Readings are taken as in the previous case, in order to assure requisite alkalinity for economical use of the phosphate chemical, and to protect the metal from any corrosion. Excess of alkalinity must be curtailed to curb bad boiling conditions (foaming) and embrittlement.

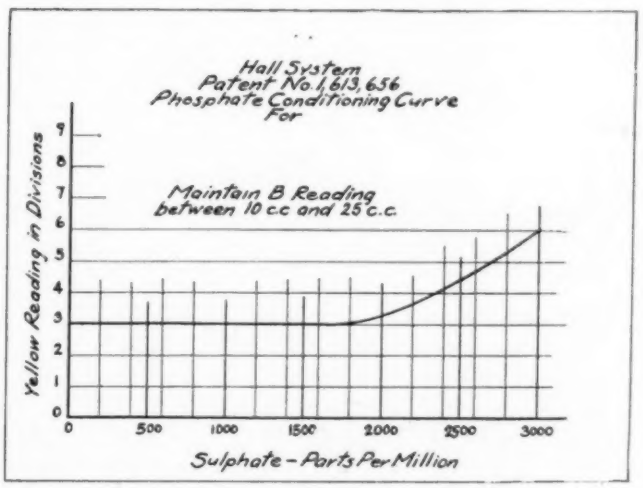

FIG. 2.

The entire generality of the curves for the operating pressures to which they refer should be noted. They stipulate in no wise how the chemical shall be added, or whether there be primary processing of

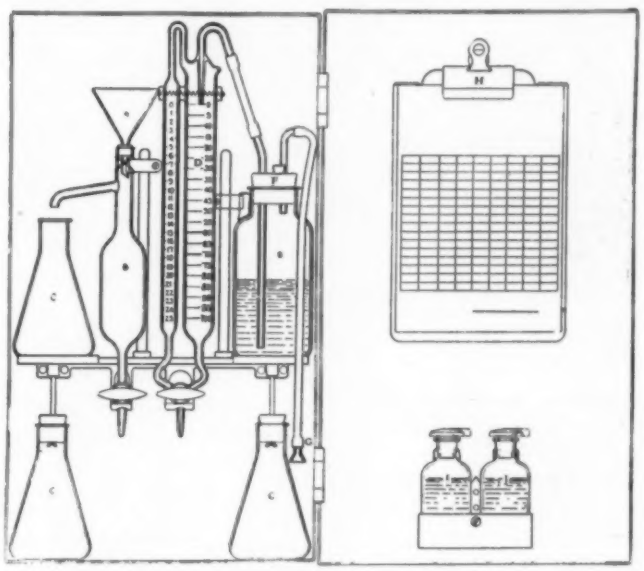

Fig. 3—Testing Cabinet Parts

feed water by a zeolite or lime-soda softener, or by an evaporator. Rather, they give concretely for each operating pressure, the safe, middle-of-the-road conditions in the boiler-water that represent sufficiency of conditioning chemical, without excess. It is the business of the operator by his tests, to keep his boiler on this road. There should be no delay in returning thereto if conditions have deviated from those that are essential, for as soon as the tests are made the operator knows definitely to which side he has strayed, and thus how to correct his position.

With any element of empiricism thus removed, the general superintendent of power need accept no alibis for poor condition of boilers. He sees to it that the conditioning chemicals are supplied to the operator. If the latter maintains conditions properly, the boilers remain clean; if he is a fault in maintenance, his records, as well as the boilers, will show it. If, perchance, his records should look good, but the boilers look bad, the superintendent is justified in crediting the operator with carelessness

or worse, and in taking appropriate measure to eliminate any such anomalous conditions.

Routine Tests

Considerable care has been necessary to make the routine tests simultaneously simple and dependable.

In titrating a boiler-water to obtain the amount of soda ash therein, it is in many, if not nearly all cases inadmissable to use the ordinary double titration with phenolphthalein and methyl orange as indicators, since organic contamination which is present to lesser or greater degree in practically all boiler-waters interferes with correctness of results. Therefore, it has been necessary to devise a method

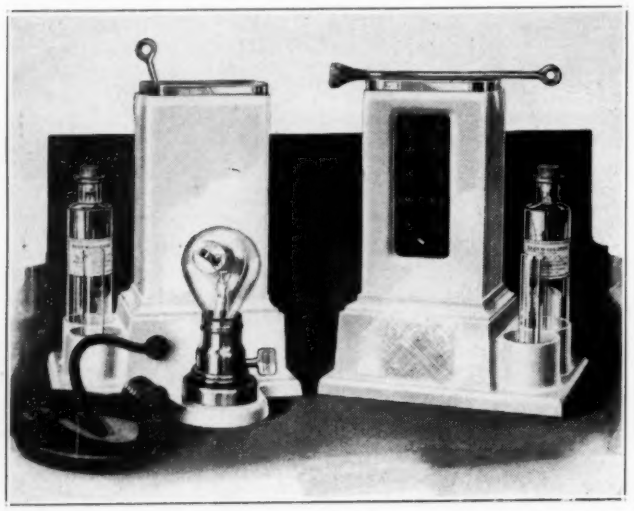

FIG. 4.

whereby titrations are made by using only one indicator; namely, phenolphthalein.

Titration of two samples is required, but filtration thereof is dispensed with. So satisfactory are the results that in our work we extend use of the method even to the control of a lime-soda softener.

The sulphate concentration is obtained by the equipment shown in Figure 4. The method consists in adding barium chloride to a sample of filtered boiler-water, whereby a fog is produced, and by dilution to a predetermined point the sulphate concentration is indicated by a direct reading scale.

The phosphate concentration is determined in the gauge shown in Figure 5, and consists in precipitating the phosphate in the sample in the form of a yellow precipitate, a color that distinguishes it and gives certain evidence to the operator that this phosphate is present. The amount present in the boiler-water is read directly off from the stem of the gauge.

Reports of Boiler-Water Conditions

The problems that come up in the operation of a boiler are well illustrated by reference to some of the reports of these titrations that have been obtained under actual operating conditions. Thus the data in Figure 6 are from a plant in which the make-up water is treated by a zeolite system and then evaporated. The operating pressure is 275 pounds. The blow-down is small and hence materials getting to the boiler-water through spill-over of the evaporator and condenser leakage concentrate to give the boiler-water concentrations indicated under the heading "Sulphate". This report is of particular interest in showing its relation to a search for leakage of raw water that was hard to find. The quantity of phosphate that was required to produce available phosphate in the boiler-water suddenly increased, indicating that a larger supply of calcium was getting to the boiler-water at some point. Note particularly the comments of the operator. He realizes that the available phosphate in the boiler-water is low at times, and is making every effort to find the source of his raw water leak and eradicate this condition. A week later he wrote as follows: "We have found and repaired the float valve on our air liberating tank which was sticking due to a worn shaft. This would stick closed or open. When open, it would pull our head tank down low and our raw water float valve would cut in. We were unfortunate not to have discovered this, for it never occurred when a check of the valves or telltales were examined."

Fig. 5—Phosphate Concentration Gauge

We would like to emphasize the fact that because of the definite control on the boiler-water this trouble was found, not when the boiler was opened and found dirty, or because of its forced opening through burned out tubes, but was recognized when it started and was taken care of by increasing the phosphate until it was remedied. That is the type of insurance obtained by following closely the maintenance of essential conditions in the boiler-water.

Another example is shown in Figure 7. In this

case the operating pressure is 400 pounds. The make-up is all evaporated but the condenser leakage is sea water, and therefore heavy in calcium. The comment that increase in condenser leakage has been caught immediately and the conditioning chemical introduced to take care of it, is the factor we wish to emphasize.

Date	Hour	Boiler No.	Sulphate	Red	Blue	Yellow	Chemical Added NA3 PO4	NA2 CO3	Blow Down Seconds
1-11	9.30	1	250	16		0.8	....	.	..
1-11	10.00	2	400	18		0.7	....	.	..
1-11	10.30	4	500	38		2.3	24.5	0	..
1-12	9.00	5	450	58		3.+	....	.	..
1-12	9.30	7	600	59		2.7	....	.	..
1-12	10.00	8	400	18		.3	21.1	0	..
1-13*	....	.	...	..		...	24.7	0	..
1-14	10.00	1	300	18		0.5	....	.	..
1-14	10.30	2	400	20		1.1	....	.	..
1-14	11.00	4	400	35		1.4	10.2	0	..
1-15	10.00	6	250	10		1.2	....†	.	..
1-15	10.30	7	1000	65		3.+	....	.	60
1-15	11.00	8	450	20		.3	36.4	0	..
1-16	10.00	1	250	16		0.4	....	.	..
1-16	10.30	2	350	20		0.4	....	.	..
1-16	11.00	4	400	39		1.3	25.7	0	..
1-17	9.30	6	250	13		0.6	....	.	..
1-17	10.00	7	750	56		3.+	....	.	..
1-17	10.30	8	500	21		0.6	25.1	0	..
1-18	9.00	1	500	22		1.2	....	.	..
1-18	9.30	2	450	23		0.7	....	.	..
1-18	10.00	4	550	39		2.4	48.3	0	..

*Sunday. No analyses.

†Was for repairs. Put 25 pounds of NA3-PO4 and 15 pounds of NA2-CO3 in front drums.

We have a few yellow readings below the curve this time, since the boiler inspection, not having individual feed of chemicals to each boiler, we have to switch our operation of some boilers to assist in raising the chemical content. Our present feed, as you see for the 17th and 18th, is O. K., and no scale should have started in those few days. No. 2 and 8 boilers were slightly below curve. Our Red reading is now at a safe point, although our leak of raw water still continues. No. 1 condenser has been tested and no leaks found. We contemplate opening No. 3 again this week and test it for leakage.

Fig. 6

DAY ENDING, JULY 23, 1928

Feed Water

Total water to boilers, lbs.....19,349,000
Total water blown down, lbs..... 163,500
Total water evaporated, lbs.....18,856,500

Chlorine in Condensate

Condenser No. 1, ppm..... 8
No. 2, ppm.....11

Chemical Added, ppm.

Condenser	Tri Sodium Phosphate	Sodium Carbonate (Soda ash)
No. 1.....	...	....
No. 2.....	...	....
Total	4.8	2.75
Specified	7.5	2.60

Boiler Water Analysis, ppm

Boiler No.	Chlorine Cl	Phosphates P 0 4 Total	Phosphates P 0 4 Available	Caustic OH	Solids Suspended	Solids Dissolved	Solids Total
1	70	..	Trace	29	Blown	Empty	..
2	40	..	Trace	14	Blown	Empty	..
3	420	..	35	167	..	..	..
4	..	..	..	..	..	..	..
5	170	..	Trace	71	Blown	Empty	7-22-28
6	50	..	Trace	31	Blown	Empty	..

Remarks: Increased condenser leakage over week end utilized all available phosphate. Doubled on trisodium phosphate treatment.

Fig. 7

These examples are sufficient to indicate the exactitude and promptitude of control obtained when the operator who makes tests on the boiler-water is thoroughly acquainted with their meaning. Because his control curve is in his own hands, he is in a position to rectify at once any unsatisfactory conditions. This gives insurance against damage resulting from any unexpected conditions that may arise, because they are caught by the tests when they occur; and any deleterious effects are discounted by control of the boiler-water during the time required for their elimination. Further, the records of the tests are of inestimable value in case of anything happening to the boilers, because they give definitely those conditions that have prevailed in preceding months or years. If those conditions have been correct the boiler operator is free from blame because he has done his best.

EXAMPLES OF WATER CONDITIONING

The examples that follow are actual cases chosen to illustrate various problems that must be met in conditioning waters.

Waters 1a and 1b. Table 1. These well waters are used in varying proportions as feed water for a cross drum boiler of 425 lb. operating pressure and all raw water make-up. The feed water heater is of the open type, well vented, and operates at or above normal boiling temperature. Primary removal of calcium and magnesium is made by a hot process lime-soda softener, and final protection of the evaporating surfaces because of the operating pressure involved, is obtained by careful maintenance in the boiler-water of the necessary concentrations of stable scale-preventing radical, phosphate.

With or without continuous blow-down, the concentration of dissolved substances in the boiler-water is high, and hence every precaution has had to be taken to protect the superheater from carry-over of boiler-water with the steam. Saponifiable contamination in the boiler-water is almost nil. The feed water regulator is quickly responsive, and maintains uniformity of water level. The steam nozzle is guarded by a vertical baffle against which steam from the cross-over tubes impinges, and by a purifier discharging to a well-vented trap. It is absolutely essential that this trap be in excellent condition at all times, else loss of superheater tubes quickly occurs.

There are phases of interest in every case. When

this boiler has been in actual operation for about six months, leakage occurred at a seam, and the question of embrittlement was raised. The value of definite records on the boiler-water was then fully illustrated, for during the period in question over 375 determinations of alkalinity, sulphate and phosphate had been made as routine tests, the large number arising from variability of feed water and the consequent close control deemed necessary. According to these analyses, if embrittlement had occurred, ratios recommended for its prevention must be unavailing. (24)

TABLE I.

ANALYSIS OF VARIOUS FEED WATERS

In Parts Per Million

	1a	1b	2	3	4	5	6	7	8
HCO_3	260	97	244	104	9	25	447	74	0
SO_4	44	262	24	10	9	7	17	13	138
Cl	369	58	9	7	1	5	21	15	10
SiO_2	10	16	19	8	4	5	15	--	18
Fe+Al	2	6	1	1	0.1	8	--	7	11
Ca	47	106	39	27	4	16	99	20	25
Mg	11	31	30	8	1	2	31	5	8
Na+K	288	28	20	4	2	--	17	11	7
H_2SO_4	0	0	0	0	0	0	0	0	33
Temporary Hardness as Calcium Carbonate	163	80	200	89	8	21	366	61	0
Permanent Hardness as Calcium Carbonate	0	313	21	15	7	28	9	10	96

Needless to say, caulking of the seam was the requisite remedy. The point to be emphasized is that no blame in any event could attach to those responsible for operation since the records are indisputable evidence that they had followed the best recommendations known for avoidance of embrittlement.

Heavy though the feed waters are in calcium and magnesium, careful control of softener and boiler-water has resulted in no outages whatever for a year and a quarter because of tube losses, or necessity for turbining. Those two words, "careful control" signify not only good but immediate routine testing of samples, and as immediate action according to the results thereof.

Water 2. Inasmuch as the operating pressure is 150 pounds, final conditioning by carbonate is feasible. Because of the considerable bicarbonate hardness, a lime-soda softener would be the preferred equipment, but until funds are available for its purchase, direct conditioning by soda ash is being used. Naturally, sludge collects in quantity in the heater, but the evaporative surfaces are clean.

Water 3. In this case, the operating pressure is 185 pounds and high rating and water-cooled side walls make thoroughly clean surfaces obligatory. The raw water make-up is 40%. Final conditioning by phosphate is best suited for certainty of clean evaporative surfaces, and for simultaneous maintenance of low enough alkalinities so that embrittlement ratios may be adhered to. These conditions are representatives of the dividing line on one side of which economy would require a primary treatment by softener followed by stable radical to control the equilibria at the evaporative surfaces; on the other side of which economy lies in direct use of stable radical without primary treatment. In this case, direct conditioning by phosphate is used; but with a greater degree of hardness in the water, or if raw water make-up were 60% for instance in place of 40%, the outlay necessary for installation of softener might well be justified.

The conditions pertaining to Water 7 are quite similar to those of Water 3, except that the operating pressure of the boilers is 400 pounds. Here, again, direct conditioning by phosphate has presented no difficulties.

Water 4. The conditions are 100% raw water make-up, 400 pounds operating pressure. Use of zeolite or lime-soda softener offers little advantage, and direct conditioning by phosphate is used.

The dominant feature of this water is its content of organic contamination. In spite of its purification for city use, concentration thereof ten or twenty times results in marked coloration, and the boiler-waters are distinctly brown. Only part of the organic matter is saponifiable, but is sufficient to cause bad boiling conditions if hydroxide alkalinity in the boiler-water is not carefully limited. From the standpoint of embrittlement ratios, and of boiling conditions, therefore, an exact upper limit to concentration of hydroxide alkalinity is essential; on the other hand ,its concentration must no fall much below 25 p.p.m., else increasnig solubility of calcium phosphate, in step with decreasing pH value, may allow calcium sulphate to become solid phase in equilibrium with the boiler-water and therefore to be deposited as adherent scale.

Of especial general value is the possibility noted in this case of maintaining simultaneously pleasingly low concentrations of hydroxide in the boiler-water, and cleanliness of surfaces in contact therewith. Under these conditions, concentration of sulphate need not be extremely high for maintenance of the sulphate-alkalinity ratios requisite to meet the recommendations of the Boiler Code on prevention of embrittlement. This is beneficial in that artificial addition of sulphate is less frequently necessary, and because of lower concentration of dissolved solids in the boiler-water, boiling conditions are better. Then, too, if incidental lapse in maintenance of the embrittlement ratios occurs, the low hydroxide concentration can at worst exercise but slow deteriorating influence on the boiler metal.

Water 5. The operating pressure is 275 pounds; the make-up is practically 100% raw water. The calcium content and per cent. of make-up of this filtered water are high enough perhaps to justify installation of a softener. However, space therefor is not available, since the softener would have to be of very large capacity. Hence, direct conditioning by phosphate has been used.

One of the questions that had to be answered by observation in this case was whether sludge accumulation at the 90° bend of the side-wall tubes close to their point of juncture with their header might present a serious problem by restricting cir-

(24) Suggested Rules for Care of Power Boilers, Sect. VII., Par. CA-5, A .S. M. E. Boiler Construction Code, (1927).

culation. The service on side wall tubes, especially of the bare and fin tube types, is severe. In case of treatment of Water 5 by a limited amount of caustic soda, the alternate formation and disruption of scale resulted in rapid accumulation of piles of chips thereof at the bends in question. In an instance which has recently come to the author's attention, and in which the hardness of the water was similar to No. 5 in quality but less in quantity, 5 days of operation with no treatment was sufficient to cause complete clogging in the bend of a corner side wall tube.

But if equilibria are maintained in the boiler-water at these surfaces such that the solid phase is of impalpable fineness of division, formation of any chips should be impossible, and circulation through the tubes be sufficient to prevent any accumulation at bends.

The results have fully justified all expectations. So long as the essential equilibria are maintained, the bends remain free of all obstruction.

Water 6. A primary treatment by softener is essential. Lime-soda seems the desirable type, in order to remove bicarbonate as sludge. With operating pressure of 225 pounds, practically 100% make-up of raw water and relatively high rating, assurance of complete protection of side walls from scale and simultaneous maintenance of sulphate-alkalinity ratios in accordance with the boiler code necessitate secondary control on the boiler water with stable radical.

Water 8. For one boiler house, operating pressure 250 pounds, this water taken direct from a river receives primary preparation in an intermittent lime-soda softener; final conditioning with stable radical is accomplished by addition of phosphate at the heater. In these boilers of cross-drum type, very marked differences in concentration of dissolved solids characterized samples drawn from opposite ends of the drum, until they were minimized by approximately uniform distribution of the feed water throughout its length. Conditions of this character seem common in cross-drum boilers, and should be corrected, else quality of steam from the two ends may not be uniform.

In another boiler house, operating pressure 135 pounds, this water, neutralized and purified for city use is treated in a zeolite softener. In this case, addition at the heater of soda ash provides alkalinity in the boiler-water requisite to inhibit corrosion.

Continuity of Efficiency

Deterioration of B battries in radio sets, and accumulation of scale in boilers are alike in their effect of causing gradual decrease in efficiency. Elimination of the former has occurred with rapidity; but it is difficult to eradicate the deeply-ingrained idea of many operators that a boiler cannot be operated over protracted periods, at high rating, without accumulation of scale. Nevertheless, maintenance of well-defined conditions in the boiler-water assures to the evaporative surfaces absence of scale formation, and hence uniformity and continuity of heat transfer. Regardless of pretreatment of water, scale-forming substances may gain entry to the boiler-water by various paths. Detection of such entry is automatic however in maintenance of specified conditions therein, and the replacement of desirable conditioning radical essential to recoup its losses are designated by the periodic routine tests.

CONCLUSION

It is essential that boiler-waters be conditioned to prevent the formation of adherent deposits on evaporated surfaces. It is likewise essential, for various reasons, that the conditioning chemical be not supplied in great excess.

We have summarized an investigation covering a period of some years, in which were established for all operating pressures, the safe highways; bounded on the one side by scale formation, and on the other by excess treatment with its attendant evils. We have shown the guide-posts that keep the operator of the boiler safely in the middle of the road and enable him to rectify at once any swerving therefrom.

It is our belief that the demands of modern boiler operation can be met by use of the methods herein presented, however exacting may be those demands.

Report Electric Welding Committee

By S. S. WALES, Chairman*

The use of fusion welding in the steel industry has advanced with phenomenal rapidity within the past few years, including arc welding, resistance welding, flash welding with gas welding and the thermit process taking their share of the development.

At the present time electric metallic arc welding seems to be most commonly used in general repairs and manufacturing processes where a variety of operations must be performed with the same tool. Thermit still holds an unassailable position where large portions of metal must be replaced and where cast iron is to be repaired. Gas welding appears to best fit thin material and where an exceptionally smooth finish is required, its competitor in this field being the Atomic Hydrogen Arc, which has the disadvantage of being a little less flexible than the Gas torch for hand welding.

While for speed in hand welding for general repair work and structural welding, the metalic arc has the advantage over all the other forms at this time, when

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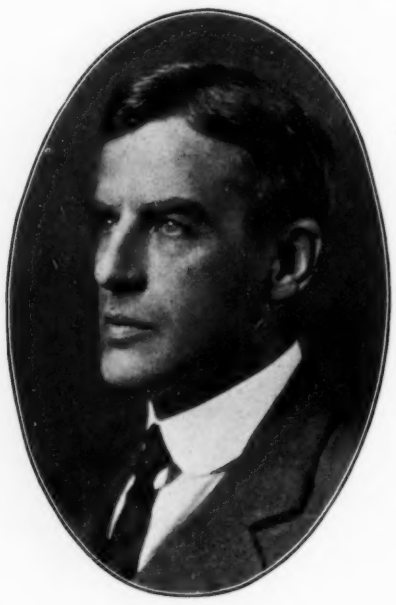
a manufacturing process is to be considered where there is a constant repetition of one operation, other forms show many superior advantages by which they take precedence over the arc process.

For the manufacture of thin wall pipe and conduit, the progressive resistance welding seem to hold an undisputed field, which may be expanded indefinitely to include larger sizes and heavier walls, as the trade becomes more familiar with the art.

For other products where sections of pipe are to be welded end to end or where pressed steel shapes are to join to form hollow members in machine construction various forms of "flash" welding are adopted. This method is now in use for making double length pipe, manufacturing automobile parts, etc., with great success and apparent satisfaction to those intermediately connected with it. For this type the time required seems to vary more or less directly with the area of the section to be welded and inversely with the current available, the voltage varying from two to nine depending on individual conditions. The time required to make a weld with a properly proportioned equipment, using about 2500 to 3000 amp. per square inch-section will vary from less than one sec. to 15 sec. where a current density of not less than 250 amp. per sq. in. is used.



S. S. WALES

Two very interesting applications of metalic arc welding in the immediate Pittsburgh district, during the past year, were the building up and repairing of the floor beams and portions of the vertical structure of the Herrs Island Bridge, which has been in service 31 years, while still in place, and the reinforcing of the body of the link bars on the Smithfield Street Bridge over the Monongahela River without interrupting traffic.

One of the most interesting departures from standard riveting practice was the complete welding of a 10,000 ton battle cruiser by Germany at their Kiel yards, showing a saving in weight of 1000 tons. This saving they translated into extra gun calibre, speed and cruising radius making it equal in power and effectiveness to a much larger class of cruisers.

At Hot Springs, Va., an addition to the Homestead Hotel was made in the shape of a central tower 180 feet high with two side wings six stories in height where electric metallic arc welding was used, to the exclusion of all field riveting for the specific purpose of avoiding the noise of the air riveters, a matter which will become increasingly important in the near future, in our large cities.

In reply to a questionnaire sent out by the Welding Committee replies were received from 33% of the steel tonnage production of the United States, showing various percentages of use of welding equipment of all kinds, the majority, however, being electric metallic arc welding equipment, and the purposes for which electric arc welding is used covered a very wide field of repair and construction work.

Of the makes of welding equipment there seem to be three favorites although 25 firms have machines represented, ranging in numbers as shown below with firms designated by letters.

A—66, B—38, C—31, D—14, E—9, F—5, G—5, H—4, I—3, J—3, K—3, and eight others at one each. Homemade machines come in for 18, equipments, a total of 207.

While it is difficult to estimate the possibilities of the market for such equipment, the following table may be of interest as comparing the personnel employed, and the number of welding sets in use, based on the annual ingot tonnage of the plants, assuming the most heavy equipped works as 100%.

The total annual ingot tonnage capacity represented here is 14,988,000.

Plant No.	Total Welding personnel	No. Welders	Annual Ingot tons per weld.	% of use	No. welders based on 100%	Increase
A	25	29	35,172	100%	--	--
B	30	22	35,272	100%	--	--
C	9	9	76,000	46%	19	10
D	15	18	77,000	45%	40	22
E	6	7	91,000	38%	18	11
F	30	21	38,500	37%	52	31
G	6	6	130,000	27%	22	16
H	12	11	134,000	26%	42	31
I	3	4	150,000	23%	17	13
J	4	4	150,000	23%	17	13
K	30	12	231,000	15%	79	67
L	2	2	312,000	11%	18	16
M	2	2	354,000	10%	20	18
N	6	4	365,000	9½%	42	38
O	5	2	701,000	5%	40	38
		93			416	324

It would appear possible that there would be an economic market, in this group, for from 300 to 350 more equipments, and in the industry of possibly 1000 but it would hardly seem that this figure would be much exceeded for general practical use for the metallic arc welder for repairs and maintenance work.

The uses to which arc welding is put in the steel mill cover a very wide range and are here presented under several heads as reported, although subject to some repetition.

Transportation:

Building up car axles and wheel flanges.
Building up rails, switch points and locomotive tires.
Repairs to locomotive frames, steel cars and tanks.
Repairs to boilers, boiler tubes and fire boxes.

Blast Furnaces:

Repairs to cracked furnace and stove shell plates.
Repairs to ore bridges and buckets.
Gas washers, dust catchers and piping.
Gas mains and bleeder valves.
Cinder pots, hot metal ladles, car frames.
Grinding pans, and building up castings.
Notch burnouts, water seals, hot blast valves.
Blowing engine frames.

Rolling Mill:

Cracked mill engine frame.

Building Up:

Roll necks, spindles, boxes and couplings.
Housings, gears, pinions, shafts.
Motor frames, armature shafts, and track wheels.

Repairs To:

Crane structures, girders, tables, pipe rollers, shears, furnace doors.

Boilers, steam and hydraulic pipe.

General Repairs To:

Blowing engine frames, hydraulic pump.

Hydraulic pipe manifolds.

Gas engine cylinders, water tanks.

Structural work in cranes, and buildings, and cast iron grid resistance.

Building up bearings, track wheels and shafts.

Complete welding of 7000 feet of pipe from 2" to 24" for steam, water and tar under pressure varying from 50 to 250# per sq. in.

In addition to the above a novel use of the metal arc is made in depositing highly refractory metal, on the surface of wearing parts of grinding and handling machinery:

Deposit on—Grab bucket teeth, steam shovel teeth, the cutting edge of prick bars, conveyors flights for handling abrasive material, wearing surfaces of crushers and grinding machinery.

The metals used are supplied in the shape of welding wire under various trade names and contain various alloys chrome, manganese, etc., and cost from 35 cents to $3.50 per pound.

These uses are only cited as examples of what has been done as assistance to those who are constantly encountering similar emergencies.

We are only at the beginning of the expansion of Electric Welding and the coming year should show still greater advances.

Portable Electric Tools in the Steel Industry: Ground Them for Safe Operation

By W. M. RUNYON*

In general the use of portable tools in the steel mills centers around the hand portable light, the electric drill, the tool grinder, and the electric welder.

The power characteristics feeding the apparatus are generally 110 to 220 volts either DC or AC.

The growth in use and design of this class of tools in the past ten years has been very rapid, their use has made work easier, faster, often less expensive, and time holds a bright future of usefulness for them.

Field operating experience of portable equipment has taught us that little was known in the past of how to properly install and handle these tools, especially from the Human Safety standpoint.

Inasmuch as your organization gave birth to this Human Safety idea years ago, it seems very fitting that you at this time through your Mr. J. S. Murray, Chairman of the Portable Tool Committee, should bring a study of this type of apparatus before you at this convention.

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Your organization is well known throughout the country for its success in Safety work. You have proved that it is good business and costs less to be human.

We electrical men have been slow in realizing that portable tools, to be of value, had to be operated by Human Beings who are in themselves high resistance creatures.

If at any time a 110 volt potential, if due to insulation breakdown to the frame, etc., comes into contact with this high resistance it sets up the necessary fractional ampere of current in the body which causes the shock hazard.

Since these portable tools have earned their spurs in industry, how then can we install them so that they will be safe for operation even under the most trying conditions?

During the last five years this question has received much research and study, by our Government, by the Electrical Committee of the N. F. P. A., and several State Compensation Labor Departments, etc. Results of this research have recently been added to

our standard national code requirements in the current issue of the 1928 N. E. Code.

Today's mandatory requirements for safe wiring of portables has been fittingly hastened due to our compensation laws and their enforcement by State departments of labor.

In addition, several of our efficient, large industrials who had experienced the shock hazard accidents, experimented, installed and found highly practical these requirements that are now National in scope and influence.

After a limited study of steel plant electrical practices and uses, it seems as though your industry has possibly been somewhat more fortunate than some in the amount of shock hazard cases to date. Nevertheless you have to a major degree throughout your plants those conditions which are conducive to this hazard, and I earnestly suggest that you give this subject due thought and face it now, rather than wait to be forced in, irrespective of whether your plant is DC or AC current.

To properly secure this shock hazard protection, it is well to focus our thoughts on the intent of these regulation requirements and why they are so written.

Their intent is: That the metal protective covering of the conductors, from the frame of the portable back to its point of service must form a low resistance capacity, emergency path to ground.

Then to carry this "Intent" into construction, first give consideration to the portable frame and its extra low resistance emergency path which is called the safety conductor back to the plug-receptacle device.

The plug-receptacle should be so constructed as to provide non-reversible polarity and insure the completion of the safety conductor ground path through it in proper relation to each other.

The safety conductor is then a part of or connected to the receptacle housing.

Next consideration is that of the protective covering for the circuit wires. This covering if conduit or metal raceway, then becomes the safety conductor path through low resistance joints on back to the point of distribution and thence to the point of service of the building, which should be connected to a water pipe or low resistance driven electrodes as conditions demand.

Should this plug receptacle be fed from an overhead open wire system with protective conduit running from the feeder to the receptacle, the conduit should be bonded to ground by connecting it to the steel frame of the building, etc.

The steel frames of buildings should be electrically bonded to ground, either to an underground water pipe or a driven electrode system.

Your Mr. Murray in preparation for his report on the use of portables issued a questionnaire requesting information on just where and what type of apparatus you are using in various departments.

The writer aided by one of these questionnaires consulted with Mr. Herlick and Mr. Weeks, Plant Department of the Crucible Steel Co. The information thus received plainly shows that the average steel plant employes portables mainly as maintenance devices.

This type of service shows your industry to be no exception to the rule. Present National Code and Labor Department regulations amply cover your requirements.

Subsequently safety grounded systems with their protective coverings and apparatus designed and approved for these purposes are now at your disposal.

Therefore with these facts in mind I earnestly suggest that you, as conditions permit, give due consideration to this subject of the protection of portable tools. By so doing you will advance your Good Safety Record and tend to reduce your compensation rate, thereby saving money; and you can feel secure in the fact that you have gone the limit to protect your human fellow associates.

Report of the Gas Utilization Committee

WALTER N. FLANAGAN,* Chairman

With Special Items By: J. W. JONES, Steam Engineer, Wheeling Steel Corporation, Portsmouth, Ohio; A. G. WITTING, Asst. Chief Engineer, Illinois Steel Company, Gary, Ind; J. C. HAYES, Combustion Engineer, Freyn Engineering Company, Chicago, Ill.; W. E. BISLER, Combustion Engineering Corporation, New York, N. Y.

The report of the Gas Utilization Committee will consist of a brief outline of the most important developments and a series of four special articles by members of this committee covering special phases of the subject.

The greatest development has been the increased realization of the value of gas as a fuel. The ease of control and the high efficiencies readily attainable have led, first, to a series of campaigns to conserve gas even to low heating value blast furnace gas, and secondly, to the more extensive use of gaseous fuel.

The first campaign has resulted in the development of better furnaces, better stoves, more effective recuperators, more efficient burners, etc.

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The second result has led to the utilization of blast furnace gas for purposes other than power and heating of the hot blast. Analyses of values have shown that blast furnace gas has a far higher value as a metallurgical fuel than as a boiler fuel. In some instances it is worth twice as much for metallurgical purposes, even when enrichment is required. Considerable investigation and several installations have been made using blast furnace gas mixed with a gas of higher calorific value, while installations are contemplated firing the gas straight, the desired flame temperature to be attained by recuperation.

The gas mixing and the utilization of blast furnace gas has been greatly facilitated by the develop-

ment of control devices and recuperators, and by the decrease in the cost of very effective gas cleaning.

There has also been developed recently a tar gasifier in order to produce a gas of very high calorific value for the enrichment of leaner gases, as well as for the conversion of pitch into the more acccurately controllable gaseous fuel.

Several individual members of this committee have prepared short discussions illustrating various phases of gas utilization. These are presented herewith.

An outstanding feature of gas utilization has been the study of the value of luminosity in gas. Mr. A. G. Witting, of this committee, has prepared the following discussion of this factor in gas utilization.

Mr. J. C. Hayes has furnished a brief outline covering foreign practice and development as well as some illustrations of the tendency toward conservation of blast furnace gas and even waste gases.

Mr. J. W. Jones further illustrates the proper utilization of gaseous fuel with an example of its application to Continuous Normalizing Furnaces.

As a further example of the use of even waste or inert gases as mentioned in Mr. Hayes' outline, Mr. Walter Bisler offers an outline of Coke Dry Quenching Practice which in addition to its interest to coke plant operators should lead the consideration of our engineers to further use of what are now considered wastes.

THE VALUE OF LUMINOSITY IN GAS

By A. G. WITTING

There exists a considerable divergence of opinion both as to the value for metallurgical combustion derived from luminosity in the flame and as to the cause of such a luminosity. As we with this word mean radiance of the flame or the power of radiation developed in combustion, the question in dispute can also be expressed thus: "Is it principally through radiation or through convection that the transfer of heat from the flame to the metal takes place?" In propounding this question in this manner, we also restrict ourselves to its application to an open hearth furnace.

The once generally accepted theory that, at least after the melting down period, the heat in the flame is mostly transmitted to the bath through radiation partly directly, partly by reflection from the furnace roof and that the radiation was due to the presence of incandescent carbon particles in the flame has of late been severely attacked.

Among others, the following well known facts were brought forth as arguments against the importance of radiation versus convection:

1. The best heating efficiency is obtained by a long flame, sweeping closely over and brought in contact with the bath, which becomes inactive where the flame ends. But as radiation is proportional to the fourth power of the absolute temperature of the flame, a concentration of combustion, i. e., the shortest possible flame, should give the highest temperature and consequently, the greatest radiating power.

2. It has been contended that an important part in the transmission of heat were taken by the furnace walls and particularly the roof which radiated downward to the bath heat absorbed from the flame, also acting as a mirror reflecting the luminant heat of the flame. Against this assumption it was pointed out that with a good working furnace the temperature of the roof is lower than the temperature of the surface of the bath and that consequently, no heat transfer between the two surfaces can take place.

3. Figures have been produced to show that the radiating power of CO_2 and H_2O is considerable and that it already at a temperature of 1500°F. exceeds the convective power of the gases. But as CO_2 and H_2O are the final products of combustion, their power would be greatest when combustion is completed, i. e., beyond the flame proper. This theory is apparently contradicted by practical experience which shows that the action on the bath ceases with the flame.

Recent studies made in Germany over the phenomenon of heat transmission in an open hearth furnace, and summarized in a paper by Dr. E. Herzog seem to have vindicated to a large extent the original theory that the transfer of heat is mainly performed through radiation although it is admitted that convection is of greater importance than once considered. It was pointed out that the products of combustion developing principally on the outside of the flame, form layers of inert gas between the flame and the roof which have a considerable power to absorb radiation and lessen the heat transfer to the roof. Similarly layers of combustion products between the flame and the bath prevent not only heat transfer by convection, but also by radiation. Furthermore, experiments have shown that the ratio of heat transmission is proportional to the distance. Consequently, the transmission of heat through radiation requires also that the flame sweeps as closely as possible over the bath.

It has also been proven by calculation that in assuming a heat transmission mainly through convection, it will be necessary to give the coefficient of transfer a much higher value than any experiments warrant. Considering that the plus pressure, which forces the gas and air into the furnace and controls their speed and direction, gradually changes into a negative pressure caused by the stack draft or exhaust fan, the end of the visible flame or completion of combustion will approximately coincide with the zero point where the draft pulls the gases away from the bath up towards the ports. Add to this that the flame temperature is gradually lowered as the combustion proceeds to completion and that the capacity of radiation is proportional to the fourth power of the absolute temperature, the heat transfer through radiation from the CO_2 and H_2O gases in the products of combustion can only be a fraction of the radiation from the actual flame and insufficient to cause the bath to boil.

This short resume of the principal arguments for and against the greater importance of heat transmission through radiation or convection may prove the right to draw the conclusions that the heat is transferred in both ways. During the melting-down period, when the piled-up scrap offers a great obstruction to the flame, causing a considerable turbulence, a condition that greatly increases the power of convection, and when the scrap also presents a very large surface for direct contact, the heat transfer is predominantly carried on through convection. But after the slag blanket has been formed, the heat transfer through convection is greatly diminished

and depends on radiation. The fact that, when coke oven gas is used as exclusive fuel introduced through a pipe directly into the furnace to burn with air entering through the furnace port from the checker chambers, the melting-down period is reduced, while often after the slag blanket is formed a foaming of the slag takes place preventing the boil, will serve as an illustration of the correctness of this assumption.

With regard to the question "What causes radiation?" the answer originally was: The luminosity of the flame and the explanation of the luminosity was that it was created by carbon particles dissociated from hydrocarbon compounds in the gas, and made incandescent by the heat before they burn with oxygen to carbon dioxide. This theory is not adequate to explain the phenomena connected with luminosity and radiation. Gases that normally burn with a hardly visible flame will, if highly preheated or with increased pressure, give a bright light. Furthermore, as previously mentioned, tests have shown that carbon dioxide and water vapor have a considerable power of radiation.

The theory offered as best explaining luminosity states that luminosity is due to vibration of the constituents of the fuel during the process of formation of the products of combustion, which vibrations are arrested by colliding molecules and transferred into heat. In other words, it is a transformation of energy. Then, higher density of the gas, higher temperature and concentration of combustion, all tend to increase the luminosity of the flame. The more intensely a body is heated, the more luminous it becomes, the more nearly white will be the light it gives off, and the greater its power of radiation. But heavy hydrocarbons which dissociate before burning and have a heat value per cu. ft. from three (CH_4) to nineteen ($C_{18}H_8$, naphthalene) times higher than CO or H_2 have correspondingly higher vibration energy resulting in a higher combustion temperature and luminosity.

On the other hand, luminosity and power of radiation are not identical. We know that the radiation coefficient, taking the so-called "black body as 1.0 is considerably lower for other substances. With a clear luminous flame without noticeable particles of fuel, the radiation is not more than 10 to (15%) of the total heat energy developed (14.9% for CH_4 and 10.4% for CO according to American Gas Association, Combustion). In this treatise the statement is made. "Luminous flames carrying particles of incandescent carbon radiate much more heat." It is claimed that CO_2 and H_2O gases have higher radiating power than other non-luminous gases, but experiments have demonstrated that the radiation capacity of a flame from a mixture of blast furnace and coke oven gas was increased four times by a small addition of benzol. The latest literature on the subject seems unanimously to express the opinion that the flame soot, i. e., the free carbon particles in the flame, constitutes the chief transmitter of heat radiation.

It may be worth to note that while we ordinarily assume these free carbon particles to be the products of a dissociation of heavy hydrocarbons (tar vapors) immediately before combustion, the presence of free carbon also may be found in gases containing no condensable hydrocarbons. The chief source in such a case is CH_4, although claims have been made that a reaction $2CO = CO_2 + C$ is possible.

The fact that coke gas with no carburizing addition has successfully been used in open hearth furnaces has often been used as an argument against the importance of luminosity as well as radiation. Analysis of the gas taken immediately at the nozzle of the burner has, however, shown the presence of free carbon. Ordinarily, CH_4 burns directly to CO_2 and H_2O. When, as the case was, a premixing burner is used, the conditions of combustion are changed. Hydrogen is the constituent of the coke oven gas that first is attacked by the oxygen in the air; a gas sample taken 12" from the burner shows that more than 50% of the hydrogen already has disappeared while the other combustibles show very small reduction. The air used for premixing, 50-50 gas and air as a rule, is barely sufficient for burning the hydrogen. Now two processes of combustion proceed simultaneously. Inside the gas cone, part of the hydrogen is burnt in confined space developing a high temperature, while on the outside along the mantle of the gas cone, the combustion takes place with the air preheated in the checkers. The result is that the gas cone heated both from the inside and outside is given a temperature higher than ordinary so that the CH_4 which has no oxygen to combine with is to a great extent dissociated into hydrogen and free carbon which give luminosity to the flame.

The dissociation of CH_4 accelerated by the presence of CO_2 and H_2O is an important factor in the application of Coke Oven gas mixed with blast furnace gas as an open hearth fuel. By carrying the two gases through the checker chambers and giving them as high a heat as possible up to 60% of the CH_4 will dissociate. Half of the carbon combines with CO_2 and H_2O to CO and H_2 but the other half of the free carbon is carried by the gases into the furnace and gives luminosity to the flame.

For such a mixed gas of average composition (33% coke oven gas and 230 B.T.U.) the amount of free carbon is practically equal to the amount of free carbon liberated by cracking in the flame of the tar vapors carried by a good quality producer gas. While some of this free carbon undoubtedly is precipitated in the checkers, observations have shown that the gases have a capacity of carrying up to 80% of the carbon in suspension. The mixed gas thus preheated will accordingly when entering the furnace have about equal radiating capacity in its flame with good producer gas. But being more concentrated it also is capable of developing a higher temperature whereby its power of radiation is further increased.

FOREIGN PRACTICE AND SOME EXAMPLES OF THE TENDENCY TOWARD CONSERVATION OF LOW GRADE AND WASTE GASES

By J. C. HAYES

An indication of the trend in gas cleaning is found in starting of a new blast furnace plant of the Australian Iron & Steel Company, Ltd., Sydney, Australia, where a plant designed by American engineers is truly American in every detail, with the exception of a gas cleaning plant, which consists of Theisen Disintegrators designed and furnished by

Eduard Theisen of Muenchen, Germany. The policy of the company was largely influenced by the experience of Koninklijke Nederlandsche Hoogovens En Staalfabrieken, Ymuiden, Holland(who started out with a standard American design of wet scrubber and later installed a complete Theisen Disintegrator Plant for washing all gas produced by two 500-ton blast furnaces, and a third blast furnace is now being built fully equipped with Theisen Disintegrators.

Indications are that the near future will see a number of gas cleaners of this type in operation in American plants. Several companies have had representatives in Europe studying the practice of gas cleaning, where over 500 Theisen Disintegrators are in operation, some of which have been in use for over fifteen years.

The Gulf States Steel Company at Alabama City, Alabama, has recently put into operation a new boiler plant, using blast furnace gas on 900 hp. boilers in combination with powdered coal, where gas is delivered to the burners at an average temperature of 330 deg. F. and preheated air at over 600 deg. F. The blast furnace gas under standard conditions has a heating average of 104 B.t.u. per cu. ft., and the actual observed flame temperature, resulting from this combination, is in the neighborhood of 2500 deg. F. A normal evaporation, equivalent to 250 per cent rating, is carried on these units with no furnace cooling other than air cooled side walls. No difficulty has been experienced in handling the dusty gas, insofar as furnace proper is concerned. The gas contains a considerable amount of zinc oxide due to the nature of the ores charged in the furnace, with the result that some amplifications of the soot blower equipment is being installed to facilitate tube cleaning. Practically perfect combustion is maintained in Freyn-Design Pressure Type Gas Burners under control of Smoot Regulators, forming part of a complete system of control for powdered coal and blast furnace gas combustion.

Extensive experiments have been conducted and equipment on a commercial scale is being installed in a European plant for the utilization of steel plant gases for the production of nitro-hydrates for fertilizer purposes, together with a separation of CO_2 gas for the manufacture of dry ice.

A number of industries foreign to iron and steel, are working along these same lines in this country and we may look forward to some interesting developments for the profitable utilization of coke oven gas and the products of combustion from blast furnace gas, in fields entirely unrelated to the manufacture of iron and steel.

FUEL FOR CONTINUOUS NORMALIZING FURNACES

By J. W. JONES

During the last year there has been considerable development work on the continuous type of furnace used for normalizing high grade sheets. Natural gas, coke oven gas, or fuel oil are the fuels usually used, natural gas being the most desirable when available. In this type of furnace an even distribution of heat at about 1850 degrees Fahrenheit is required throughout the length of the furnace and is obtained by a large number of high pressure aspirating type burners. The flame must be non-oxidizing to prevent scaling, the products of combustion showing about 2% carbon monoxide and 1.5% hydrogen.

The first furnaces were designed with water-cooled shafts with steel discs keyed to them, but due to the large heat losses causing a much lower temperature below the top of the discs, this type of shaft was supplanted by water-cooled heat insulated shafts with alloy discs. This change has reduced the gas consumption from 7500 cu. ft. to 2700 cu. ft. of natural gas per gross ton of sheets normalized. A later development is a non-cooled hollow shaft made of a heat resisting alloy which further reduces the fuel consumption although it appears that the life of the shaft will not be as long.

COKE DRY QUENCHING PRACTICE

By W. E. BISLER

An interesting example of the utilization of inert gases is the recently developed process for dry quenching of coke. For a comprehensive study of dry quenching, you are referred to a paper published in the May, 1928, issue of "Iron & Steel Engineer," by Walter Sennhauser, to a paper entitled "Dry Quenching of Coke," by D. W. Wilson and presented at the Second International Coal Conference at Pittsburgh, November, 1928, and to several excellent technical papers published in the past two years by A. M. Beebee of Rochester, N. Y.

In this method of cooling, the hot coke as it is produced at about 2000 deg. F., is placed in a brick lined chamber. A current of inert gases is continuously passed upwards through this body of coke thereby transferring the heat from the coke to the stream of gas; the hot gases, leaving the coke, then pass through boilers (usually of the fire tube type) in which the production of steam cools the gases, which, by means of a fan, are forced again into the body of coke, thus completing the cycle. The composition of these inert circulating gases—formed initially of air—is such that no burning of the coke occurs, steam being produced only from the sensible heat of the hot coke.

It is interesting to note that the sensible heat in the hot coke as it leaves the ovens or retorts accounts for about 40 per cent of all the fuel required for the carbonizing process. In the commonly used wet quenching method of cooling coke, this enormous quantity of heat is not only entirely wasted, but produces huge clouds of corrosive vapors containing much fine coke dust.

A plant now being built at Flint, Michigan, will have a capacity of 280 tons of coke daily, and from this it is expected that the daily production of steam will be about 280,000 lb. at 250 lb. pressure and 100 deg. F. superheat. The plant is so designed that by the inexpensive addition of further circulating gas fans and boilers, the capacity may be increased to 500 tons of coke daily.

The accompanying drawing illustrates the method of operation at the Flint plant: Hot coke at from 1800 to 2000 degrees Fahrenheit is pushed from the ovens into the coke car as shown in the figure. The coke car is then pushed into the cage of an elevator which lifts the entire coke car and its contents to a height permitting the discharge of the coke from the car through a short chute into the

coke container. This container is always kept practically full of coke, discharges from it being made immediately before charging it and in amount just sufficient to provide space for the fresh charge. The coke slowly passes down through this container, then through a chute to the coke wharf. From the wharf, the coke is conveyed to the screening equipment. For cooling the coke, recirculated inert gases are forced by means of a fan into the lower portion of the container, passing upward through this; they are then conducted through a superheater and then downward through the boiler fire tube type, having an outside steam drum. At the base of this boiler, there is a dust collector in which any fine coke which may have been carried out of the container by the stream of gases is deposited.

Some of the advantages of dry quenching as contrasted with wet quenching are: (1) Production of about 1000 lb. of high pressure steam per ton of coke cooled. (2) Production of coke with a uniformly low moisture content. (3) Cleaner and better coke due to the absence of moisture and of wet breeze adhering to the larger particles. (4) Less breeze and dust due to elimination of shattering by water. (5) Elimination of cost of pumping quenching water and of maintenance of wet quenching equipment. (6) Reduced maintenance of plant steel work owing to the absence of corrosive wet quenching vapors. (7) Better results in blast furnace operation, due to lower moisture, higher quality and greater uniformity of the coke.

These advantages have been demonstrated in the three years' operation of an installation at Rochester.

Report of Gas Utilization Committee, Continued

In closing this report I wish to express my appreciation for the co-operation of the members of the committee and particularly those who contributed the valuable illustrative articles which have just been presented.

Walter N. Flanagan,
Chairman.

Steam Generation and Utilization

By L. C. EDGAR*

Of all God's creatures, man is the most prodigal—he throws away his inheritance and wastes his substance.

Nature has through the sunshine of a million years grown trees and flowers year after year and treated them in her laboratory to the end that this sunshine should be preserved to us for an inheritance.

We have mined this concentrated sunshine destined to lessen the burden of man's labor and have wasted it in a way to put the Prodigal Son to shame.

The dawn of an awakening is at hand and in our generation Science and Engineering are endeavoring to conserve and preserve this inheritance handed down to us through the centuries.

The measure of this achievement must not, however, be between the accomplishments of yesterday and the accomplishments of today, but rather between the accomplishments of today and the possibilities of tomorrow, for only by such a comparison can we be humbled to a full realization of the incompleteness of our present achievements and spurred to greater efforts for the achievements of the future.

Engineers of today have a great responsibility in the utilization of our vast resources in fuels, and each and every one of us should be alive and alert to the possibilities and the developments that are achieved from time to time in the utilization of this remarkable store of fuel and do everything in our power to prevent its wasteful use or destruction.

One of the most important phases of the engineer's work is co-operation and counsel with other engineers, and it is for that purpose that we are here today. As Chairman of this discussion, I do not wish to burden you with a great deal of detail in this matter of fuel for Steam Generation and Utilization because I am not a specialist in this particular branch of engineering and because I feel that more good can be gotten out of this by an open forum type of discussion than by any paper which I could write on the subject. I do wish, however, to point out a few things which have impressed me in the way of possibilities for the future as reflected by the achievements of the past.

In the matter of size, we have been going to larger and larger units until we have now units which are delivering continuously 500,000 lbs. of steam per hour and more, and are looking forward to the regular production of 1,000,000 lbs. of steam per hour. The success of large units seems to be unquestioned—the refinements in design, the conservation of space, and the possibilities of more careful supervision over a limited number of units, all point toward larger and larger units. These larger units can have installed in connection with them all the necessary recording instruments, devices for trapping the last B.T.U., such as air heaters, economizers and the like, water cooled walls, etc., so that when all these things have been taken care of we have engineers talking 90% over-all efficiency.

This increased boiler efficiency in late years is due largely to air pre-heating, use of economizers, or to a combination of both air pre-heater and economizer, as well as to improvements in boiler design. There are many forms of air pre-heaters. The results shown by air pre-heateres have been gratifying in spite of the fact that it requires fans to put the air and waste gases through the air pre-heaters. A temperature rise in the air of 400% can readily be obtained when using blast furnace gas as fuel. This

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adds appreciably to the boiler efficiency as well as increasing its output.

Air pre-heating by means of exhaust steam has also been tried to a limited extent. To make this effective, it would be necessary to use economizers for heating feed water to a high temperature.

Then, too, in the matter of pressure, there is an increased tendency to higher and higher pressures. I can remember when I traveled many miles to see one of the first boilers generating 350-pound steam pressure, and I remember my re-action then was that we had almost reached the limit. In the light of steam pressures of 400, 500, 600, 1200, 1400 up to 1800 pounds, and possibly more, this 350-pound steam pressure unit seems almost antique, although it was only a few short years ago.

The success of these units and the development in design which make these units possible, compels every forward-looking engineer to think in terms of higher steam pressure whether he be able to apply it to his particular operations or not and to keep himself familiar with the aims and achievements in these large units.

We should have much to say in commendation for the designers of accessories such as valves and all other equipment, without which these high pressures and superheats would be impossible.

Not only has much work been done in the design and development of these units, but the combustion engineer has been busy in the design of furnaces to use in connection with the larger units. The first furnaces, in the light of our present experience, were poor affairs:—burned out and had inefficient combustion. They said if you have too much turbulance you burn your furnace, therefore, we must have large furnaces; but if we have large furnaces we do not have satisfactory utilization of the fuel; but today we have many furnaces which not only have turbulance for combustion but have water cooled, steam cooled and air cooled side walls and a variety of things, all in the interest of maintenance and efficiency.

So in the steam generation, we have to summarize:—Increased larger units, Increased Pressure, Increased application of Superheat, Improved furnaces, Improved boilers, more use of Superheat, New and better baffling, Better Economizers—all to make make steam better and cheaper, whereas on the other hand, we have in the electric industry, the generator builder busily engaged making bigger and better generators; where, too, the matter of size seems to be a factor in economies and units of 100,000 kw and over are possible and in service. The compound turbine generators, single deck and double deck with all kinds of accessories, blade design and nozzle improvements to squeeze out the last k.w. per pound of steam—all these modern improvements have been in the interest of greater and greater economy.

The steam turbine which is now largely used for super-heated steam at high pressure has also been steadily improved and its efficiency increased until the price of electric power today is low compared with pre-war prices, when the price of fuel, attendance and apparatus is compared with pre-war prices.

The thermodynamic principles now helping to lower cost of electric power cost are: First, Stage Bleeding; second, Feed-water Stage Heating; and third, Higher Vacuum.

Stage bleeding is used for heating feedwater and also for supplying steam for many other purposes after removal of the power heat.

Feedwater heating by stages consists of extracting the steam from the turbine at intervals after it has done work in the turbine and then putting it through a closed heater at each stage of heating. By this means, the water temperature can be much increased above the ordinary temperature of open heaters and thus increase the cycle efficiency of the plant.

Vacuum has been improved which gives a much greater range of expansion and resultant power increase.

An additional principle of re-superheating is now being discussed. This consists of extracting the steam from the turbine after it has done some work and sending it through the re-super-heater before it does additional work in the turbine. Any heat so added to the steam gives a theoretically large power return. So far it has been considered not advantageous to do more than two stages of re-superheating for the proposed higher pressures.

Many of us are but in measure spectators upon this great procession advancing in the interest of utilization of fuel; but are we to sit back and say "that unless there be some improvements in our plants and unless we be authorized to spend money for all these improvements, we can do nothing in the interest of fuel economy?", and in reply will say "Positively no." There are many things that can be done in the interest of economy in the oldest plant—there is the waste that occurs in a multiplicity of items that grow up in every plant in spite of very close supervision and we should tighten up on our supervision of these wasteful items, such as losses through lines, poor and improperly maintained traps on steam lines and heating systems throughout plants, carelessness regarding the covering and recovering of steam lines, etc., are preventable losses which can very easily be corrected if we are alert to our responsibilities. There is the checking of the combustion of boilers, regardless of age and condition, that can be done and improvements made. There is the checking of air leaks, water leaks, steam leaks, and countless other losses, which will in the aggregate amount to a surprising figure.

I would suggest that in the discussion that will follow this introduction, that each one of you if you can, should tell of some way in which you have been able to reduce your steam cost or reduce the amount of steam required through more effective utilization. I am sure there is not a man here who has not had such an experience and believes that such a forum will enable each one of us to take back with him some tangible, concrete idea which would be a permanent benefit to the particular plant with which he is affiliated.

With this idea in mind, the meeting is now open for discussion.

F. E. LEAHY, Chairman, Thursday, June 20, Combustion Engineering Session.

RUSSELL R. SHEPHERD, Chairman, Registration Committee.

C. L. BAKER, Chairman, Safety Engineering Division Session, Monday, June 17, 1929.

J. J. BOOTH, Chairman, Shop Practice Committee.

W. E. MILLER, Chairman, Formal Reception Committee, Thursday Evening, June 20, 1929.

S. G. HIBBEN, Author, A Lighting Survey of Steel Plants.

WALTER N. FLANAGAN, Chairman, Wednesday, June 19, Combustion Engineering Session.

J. S. MURRAY, Chairman, Portable Electrical Tool Committee.

L. C. EDGAR, Chairman, Tuesday, June 18, Combustion Engineering Session.

A. I. & S. E. E. Convention and Iron and Steel Exposition

Special Features

Monday, June 17th

12:30 P. M. "Get-to-gether Luncheon." Everybody invited. Members, Guests, Exhibitors and their Ladies. Italian Dining Room, Main Lobby.

7:00 P. M. Official Opening of Iron and Steel Exposition, Main Lobby.

7:30 P. M. Electric Locomotive controlled by Voice over Radio, Main Lobby. Chairman, C. S. Proudfoot, Manager of Works, Vanadium Corporation of America, Niagara Falls, N. Y.

9:00 P. M. Informal Reception, Italian Dining Room, Main Lobby. Features, Entertainment and Dancing. Members, Guests, Exhibitors and their Ladies invited. Chairman, Mr. A. A. Stewart, Electrical Engineer, Pittsburgh Steel Co., Monessen, Penna. Registration Cards and Exhibitor's Passes admits.

Tuesday, June 18th

8:30 A. M. Engineering Breakfast, Italian Dining Room, Main Lobby. Everybody invited. Members, Guests, Exhibitors and their Ladies. Make Reservations at Registration Desk in Main Lobby.

1:00 P. M. A. I. & S. E. E. Ladies' Bridge Luncheon, Keystone Athletic Club, Pittsburgh, Penna. Make Reservations at Registration Desk.

Wednesday, June 19th

10:00 A. M. A. I. & S. E. E. Ladies' Sight-seeing Trip in Pittsburgh and Environs. Make Reservations at Registration Desk.

Thursday, June 20th

1:00 P. M. Jones and Laughlin Steel Corp., Inspection Trip, Aliquippa plant, Aliquippa, Pa. Trip must be made on Special Train which leaves P. & L. E. Southside Station at 1:00 P. M. (D.S.T.) Cars will be switched right into Aliquippa plant. Reservation must be made for this trip at Registration booth in Main Lobby. Members, Guests and Exhibitors invited.

9:00 P. M. Formal Reception and Dinner Dance featuring Richard Crooks, celebrated Opera Soloist. For the dancing, Don Bestor presents his Victor Recording Orchestra. Tickets on sale at Registration Booth in Main Lobby. Chairman, Mr. W. E. Miller, Electrical Engineer, Bethlehem Steel Company, Johnstown, Penna.

ADVERTISING PAGES REMOVED

A. I. & S. E. E. INSPECTION TRIP

Jones & Laughlin Steel Corporation - Aliquippa Plant - Aliquippa, Pa.

June 20th, 1929

Members, Guests and Exhibitors invited. Trip must be made on Special train which leaves P. & L. E. Southside Station at 1:00 P. M. (D.S.T.). Cars will be switched into Aliquippa plant. Reservations must be made for this trip at Registration Booth in Main Lobby.

Schedule and Route, A. I. & S. E. E. Inspection Trip

1:30—Arrival

North Mills

1:35-1:50 Blast Furnace Dept.
1:52-1:57 Blowing Engines
2:00-2:10 Open-hearth Dept.
2:10-2:20 Converting Dept.
2:20-2:25 Mould Yard
2:25-2:30 Soaking Pits
2:30-2:40 Blooming Mill
2:40-2:45 Bar and Billet Mills
2:45-2:50 Skelp Mill
2:50-3:20 14″ Rolling Mill
Rolling J. & L. Junior Beams

South Mills

3:20-3:35 Transportation to Rod Mills

Wire Department

3:35-3:40 Rod Mills
3:40-3:42 Cleaning and Baking
3:42-3:45 Wire Drawing
3:45-3:47 Galvanizing
3:47-3:49 Patent Annealing
3:49-3:51 Wire Fence
3:51-3:52 Straightening and Cutting
3:52-3:54 Nail Mill
3:54-3:55 Nail Cleaning and Coating

Tin Plate Department

4:00-4:04 Hot Mills
4:04-4:06 Black Pickling
4:06-4:07 Black Annealing
4:07-4:09 Cold Rolling
4:09-4:10 White Annealing and Pickling
4:10-4:13 Tinning
4:13-4:15 Assorting

Seamless Tube Department

4:20-4:25 Round Mill
4:25-4:35 Seamless Hot Mills
4:35-4:40 Seamless Finishing

Welded Tube Department

4:45-4:48 Galvanizing
4:48-4:54 Butt Welding and Finishing
4:54-4:57 Coupling Shop
4:57-5:00 Lap-weld Welding

ALIQUIPPA WORKS

The Aliquippa Works includes 488 rectangular coke ovens, with waste heat boilers, with an annual capacity of 450,000 net tons of coke; 122 by-product coke ovens with an annual capacity of 800,000 net tons of coke; by-product and benzol plant for recovery of light oil, ammonium sulphate, fuel tar and fuel gas; 5 large blast furnaces; 4 Talbot open hearth furnaces; 3 Bessemer converters; 1 blooming mill; 1 continuous billet mill; 1 continuous sheet bar and skelp mill; 1 10-inch skelp mill; 1 14-inch straight-away merchant mill; 2 continuous wire rod mills; 358 wire drawing blocks; 227 wire nail machines; 2 spring steel patenting furnaces; 4 staple machines; 125 barbed wire machines; 8 field fence machines; 3 galvanizing pans; 69 sheet and pair furnaces; 32 hot tin plate mills; 10 trains of tin mill cold rolls; annealing furnaces; 31 tinning stacks; 4 butt weld pipe furnaces; 3 lap weld pipe furnaces and 2 galvanizing units; 2 seamless tube mill units for making seamless pipe from 2⅜″ to 13⅜″ complete with finishing and shipping facilities, and also complete equipment of auxiliary plants, utilities and facilities.